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Effect of Hazardous Material Spills on Biological Treatment Processes

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The effects of over 250 chemical substances on biological treatment processes are presented in a format which permits its use as an operations handbook. The information, arranged in a matrix form with the chemical substances presented in alphabetical order, includes descriptions of the chemical; its effects on treatment process operating parameters, especially those associated with the activated sludge treatment process; and the effect of the treatment process on the chemical. Data from full scale, pilot scale, and bench scale studies are reported. An extensive bibliography related to the effects of hazardous materials on biological treatment processes also is presented.

Use of the handbook with companion documents detailing contingency plans and response countermeasures to mitigate the effects of spills of these hazardous materials is recommended.

This report was submitted in fulfillment of Grant Number S-801123, by Environmental Quality Systems Incorporated under the (partial) sponsorship of the Environmental Protection Agency. Work was completed as of October 1974.

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ON
BIOLOGICAL TREATMENT PROCESSES

by

Andrew P. Pajak
Edward J. Martin
Environmental Quality Systems, Inc.
Rockville, Maryland 20852

and

George A. Brinsko
Frederick J. Erny
Allegheny County Sanitary Authority
Pittsburgh, Pennsylvania 15233

Grant No. S-801123

Project Officer

John E. Brugger
Oil and Hazardous Materials Spills Branch
Industrial Environmental Research Laboratory-Cincinnati
Edison, New Jersey 08817

INDUSTRIAL ENVIRONMENTAL RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
CINCINNATI, OHIO 45268

DISCLAIMER

This report has been reviewed by the Industrial Environmental Research Laboratory-Cincinnati, U.S. Environmental Protection Agency, and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the U.S. Environmental Protection Agency, nor does mention of trade names or commerical products constitute endorsement or recommendation for use.

FOREWORD

When energy and material resources are extracted, processed, converted, and used, the related pollutional impacts on our environment and even on our health often require that new and increasingly more efficient pollution control methods be used. The Industrial Environmental Research Laboratory - Cincinnati (IERL-Ci) assists in developing and demonstrating new and improved methodologies that will meet these needs both efficiently and economically.

This report is a product of the above efforts. It may be used by the treatment plant and collection system operator as an adjunct to other reference works to assist in meeting day-to-day needs. The information may be used to improve the understanding of operating conditions under the circumstances imposed by hazardous material spills. Further information may be obtained by contacting the Oil and Hazardous Materials Spills Branch of IERL-Ci at Edison, New Jersey 08817.

David G. Stephan
Director
Industrial Environmental Research Laboratory
Cincinnati

ABSTRACT

The effects of over 250 chemical substances on biological treatment processes are presented in a format which permits use as an operations handbook. The information, arranged in a matrix with the chemical substances presented in alphabetical order, includes: descriptions of the chemical; effects on treatment process operating parameters, especially those associated with the activated sludge treatment process; and the effect of the treatment process on the chemical. Data from full scale, pilot scale, and bench scale studies are reported. An extensive bibliography related to the effects of hazardous materials on biological treatment processes also is presented.

This report was submitted in fulfillment of Grant No. S-801123 by Allegheny County Sanitary Authority (ALCOSAN) and its sub-contractor, Environmental Quality Systems, Inc., under the partial sponsorship of the U.S. Environmental Protection Agency. The Grant Project Period extended from June, 1972 through June, 1976. Corrections of the final report were completed in September, 1977.

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The authors appreciate the continued advice and support of Dr. John E. Brugger of the Industrial Environmental Research Laboratory of the EPA at Edison, New Jersey. His assistance was invaluable.

SECTION I

INTRODUCTION

The Allegheny County Sanitary Authority (ALCOSAN) has initiated a comprehensive program for the management and control of hazardous materials within its service area. One of the major goals of this program is to minimize the effects spilled hazardous materials have on the performance of ALCOSAN's and other biological wastewater treatment facilities. To estimate the scope and nature of effects which may be anticipated for a broad variety of hazardous materials and to determine the extent of previous work in this area, the literature was reviewed.

The objective of this review was to develop a concise compendium of the effects of hazardous materials on biological treatment processes for plant operating personnel. It was intended that operators, when faced with hazardous material spills, could use this handbook as a quick reference in assessing the range of potentially adverse effects on the treatment process. Although remedial action and countermeasures are not suggested as part of the handbook, this document together with a formal operations contingency plan may be expected to identify possible means for mitigating such adverse effects.

The sensitivity of biological treatment processes to changes in influent waste characteristics has long been recognized. In the past, this has been accepted as an unfortunate characteristic of secondary treatment. However, recent emphasis on consistency of treatment plant performance and effluent quality demands that more attention be paid to the effects of variable waste characteristics. This is particularly important for hazardous material spills. Treatment plant performance can be influenced by such spills in a number of ways, including:

1) Direct toxicity of chemicals to micro-organisms.

2) Inhibition of biological processes leading to incomplete treatment.

3) Exertion of BOD after treatment by slowly degradable material.

4) High effluent COD concentrations caused by refractory material.

5) Disruption of sludge treatment systems.

6) High oxygen demand which results in development of an anaerobic or suboptimal bioreaction environment.

Currently, it is difficult to predict the response of biological treatment to hazardous material spills. Little firm data on full-scale plant experience is available because the results of accidental spills are not measured readily and data usually is very general in nature. Pilot scale testing is practical but little work has been done to date. Often industrial wastes are studied on a pilot plant scale to yield design data; however, in these cases the wastes almost always are a mixture of product, by-products, intermediate compounds and raw materials. The exact composition usually is not known. Hence, most of the literature uncovered in this effort cites bench and laboratory scale work.

Bench-scale tests with small reactors have been used for preliminary design studies and can yield useful information on the effect of biological treatment on a pure compound (and vice versa) under conditions simulating real operations. Respirometer studies can be used to indicate toxicity and degradability of materials. Oxygen uptake rates also are useful in predicting the effect of rapid oxygen demand on full-scale aeration systems. BOD tests can give an indication of the degradability of the material studied.

Care must be exercised in extrapolating the results of such studies to full-scale aeration systems. Conditions under which the study was done are, most likely, different from treatment plant operating conditions. The important differences may include:

1) Concentration of chemical added.

2) Degree of acclimation of micro-organisms to chemicals at different concentrations.

3) Aeration rate.

4) Type of treatment (e.g. conventional activated sludge, extended aeration, trickling filter, etc.).

5) Concentration of mixed liquor suspended solids in activated sludge treatment plants.

6) Temperature.

7) Detention time.

8) Presence of other materials.

Many pure compound respirometer studies are conducted at high concentration levels (e.g., 500 mg/l or greater). For a large treatment plant with a capacity of 150 MGD, almost 80 tons of chemical dumped over a 6-hour period (a typical aeration tank detention period) would be required to maintain an influent concentration of 500 mg/l for the same interval.

Respirometer studies do not reflect operating conditions in a treatment plant. Also, chemical compounds used for experimentation may not be found as such in real wastes.

Thus, the data presented in this review cannot be transferred directly to a particular plant. Its utility lies in providing an indication of chemicals that can cause problems in biological treatment and relative effects on treatment plant performance and effluent quality.

SECTION II

CONCLUSIONS

Often the wastewater treatment plant operator must contend with spilled hazardous materials which enter the sewerage system. Generally, he has little basis for predicting the extent to which these materials may affect treatment plant performance. As a prelude to initiating suitable countermeasures to prevent plant upset or equipment damage, the operator must have information related to potential effects readily available. The information in this handbook provides a firm basis for preventive and restorative actions on the part of operating personnel.

The handbook is a compilation of considerable information which operators can use quickly. When coupled with a well-conceived contingency plan, this document can permit rapid response to maintain treatment plant operation. The handbook is not intended to be all-inclusive, and extensive additions and updates may be necessary as time passes; however, it does provide a vital and much-needed beginning in coping with an increasing frequency of spills of a constantly expanding list of hazardous materials.

A significant conclusion reached from the critical evaluation of the large volume of technical data reviewed is that there is little definitive information on the number and extent of treatment plant upsets and, particularly, on the actual causes of the failures of the plants to meet effluent standards and guidelines. Too few "post mortems" are either undertaken or reported.

SECTION III

RECOMMENDATIONS

Research engineers and scientists are encouraged to add to the base of information contained in this handbook because:

1. Information on hazardous material effects is modest but is increasing rapidly.

2. More information on full scale plant incidents is needed.

3. No work has been performed on many frequently used hazardous materials.

4. New and potentially hazardous materials continue to enter the market place.

5. There is a dearth of information on contingency plans and countermeasures, particularly in terms of differing biological treatment plant configurations.

Experiences with full scale plant operations would be especially valuable in updating this initial effort.

Likewise, a companion document on contingency plans and response countermeasures is a distinct need in order for operating personnel to take full advantage of the information presented in this handbook. Such a document should be designed to permit personnel at each specific plant to tailor their response(s) to their particular situation.

While the list of hazardous materials in this review is extensive, it is not all-inclusive. A project of greater scope could provide revisions to the foundation presented here and result in a more complete reference. Additionally, new research results can be expected as time passes; therefore, it is recommended that periodic revisions be undertaken to ensure continuing utility of the handbook.

SECTION IV

LITERATURE SELECTION CRITERIA

The data and information compiled and evaluated during the review encompassed nearly two thousand documents which were identified as dealing with materials of potential interest. Abstracts for over a thousand of the documents were examined if the titles appeared to be relevant to hazardous material effects. Approximately five hundred articles were reviewed in depth, and ultimately almost one hundred literature references were utilized in preparing a matrix of hazardous material information. The matrix format will be described in detail later.

Evaluation of the effects of all potentially hazardous substances clearly was beyond the scope of this review. It was recognized at the outset that a discriminating approach was needed to provide useful information in a concise form.

Therefore, specific criteria were developed to ensure a useful compilation of hazardous material effects data that is both manageable in size and informative in content. The following criteria were used to select literature references for review:

1. A preferred article described work with a substance(s) having documented effects. Given the elasticity of available definitions, a substance was identified as a possible hazardous material by occurrence in one or more of three sources. First, the preliminary list of toxic pollutants developed by EPA was considered. This list includes nine broad classes of substances which are known to have adverse effects on biological treatment processes. Second, a list of thirteen substances was prepared which were derived from public testimony in reaction to the initial EPA announcement. Third, the technical literature itself yielded many valuable additions to the list by virtue of the amount of attention devoted to certain materials by investigators.

2. A preferred report in the technical literature presented the results of a test conducted on a scale large enough to suggest applicability of the resulting data and information. Therefore, results from bench, pilot, or full-scale tests were selected preferentially and respirometer and bottle test data were included only when larger scale work was unavailable. Data derived from unique laboratory conditions and primarily of theoretical interest were excluded.

3. The purpose of the literature review was to obtain data and information that could lead to an understanding of hazardous material effects following a spill. Unless no other relevant work was available, references which described short term or "shock" loadings were selected preferentially over those describing continuous or semicontinuous operations.

4. A preferred article or report contained enough data of sufficient quality to ensure that the results of the review would yield useful information.

SECTION V

MATRIX PREPARATION

Because of the large quantity and wide diversity of information obtained in the literature review, it was necessary to devise a standardized format for presenting data in order to assure maximum utility by operations personnel. Hence, the information gathered was arranged in a convenient matrix (Figure 1) containing the following information:

Column 1: the chemical being studied;
Columns 2-5: the classification and nature of the chemical;
Columns 6-7: the effect of the treatment process on the chemical;
Columns 8-9: the effect of the chemical on process operating parameters; and
Column 10: the conditions of the study.

The user will note the ways in which the chemicals are classified (Columns 2 through 5) and the detail provided. Columns 2 through 4 are typical descriptors (i.e., inorganic or organic, acid or base, substituted or unsubstituted hydrocarbon, aromatic or non-aromatic, etc.); while Column 5 locates the chemical in one of 23 classes. Wastes containing unidentified or many different compounds, e.g., Brewery waste, have not been assigned classifiers. Three columns were used for typical descriptors for ease in comparing different materials; it was felt that stacking the descriptors in one column would look more confusing.

The effects of hazardous materials may be similar among materials in the same class (e.g., heavy metals), and the plant operator will probably be limited in his range of responses to a spill. Consequently, in specific situations which the plant operator will discover through his experience at his facility and in cases where no information is provided in the handbook or where additional information with regard to effects is needed, he may refer to the effects of other materials within a class.

The attention being paid to effects of hazardous materials vis-a-vis waste treatment at publicly-owned plants is relatively recent and a direct result of the 1972 Amendments to the Federal Water Pollution Control Act. Many different modes of classification are to be found in the literature and several are the result of previous work by federal agencies; the U.S. Coast Guard, the Federal Trade Commission, the Interstate Commerce Commission, and others. Eventually a single classification code may become standardized.

FIGURE I

LITERATURE MATRIX FORMAT

1	2	3	4	5	6	7	8	9	10	11	12

(1) Chemical
(2) Classification of the Chemical
(3) Classification of the Chemical
(4) Classification of the Chemical
(5) Nature of the Chemical
(6) Effects of the Treatment Process on the Chemical: Chemical Concentration(s) Studied
(7) Effects of the Treatment Process on the Chemical: Percent Removal of the Chemical
(8) Effects of the Chemical on Process Operating Parameters: Parameter Studied
(9) Effects of the Chemical on Process Operating Parameters: Description of the Effects
(10) Conditions of the Study
(11) Remarks
(12) Literature Reference Number

The chemicals in the EFFECTS MATRIX are arranged in alphabetical order. Background, process variables, operating parameters, and other characteristics of cited studies are given in coded form for each chemical. Tables 1 through 4 list and describe various codes used in the EFFECTS MATRIX. The user of this handbook may use this coded information to assist in interpreting the applicability of the data to a specific set of plant operating conditions. The reference numbers in the EFFECTS MATRIX correspond to those in the list of References (Section VIII).

In reporting the data, a number of terms or phrases have been used to characterize the response of biological systems to a particular chemical. These are generally reported as given by the author of the literature source. Further definition of some terms is given below:

1. TOD - Theoretical oxygen demand of a specific compound which is calculated based upon the complete oxidation of the chemical to CO_2 and water. It is used to indicate the maximum potential oxygen demand and is useful in judging general degradation characteristics. Some researchers use COD as a yardstick against which degradation test results are compared.

2. Oxygen uptake stimulation - used in respirometer tests to indicate that the addition of a compound caused the bacteria to increase their utilization of oxygen. It is interpreted as meaning that the compound is biodegraded.

3. Toxicity or inhibition - In respirometer tests, toxicity is used in reference to conditions where the oxygen uptake of microorganisms with addition of the test chemical is less than without. Some researchers define this condition as inhibition, using "toxicity" only when no oxygen uptake occurs or when oxygen uptake is substantially depressed. This latter condition indicates that little biological activity is occurring.

In many of the literature reports, it seemed that the distinction between

a) apparent toxicity, and
b) resistance to degradation,

was either confused or not analyzed. From the point of view of the treatment plant operator the significance of differences between the two is substantial. Toxicity indicates a threat to the integrity of the activated sludge or other biological treatment processes because the organisms may cease to function until the process has recovered. Resistance to degradation may result in materials being discharged to waterways by passing through the process with little or no adverse effect on the continued capability of the process to biologically degrade other materials. Admittedly, in either case effluent standards may not be satisfied.

In many studies reported in the literature, the material being evaluated was "fed" as the only "substrate." This is particularly true of respirometer or other small scale studies. In these studies, if oxygen is utilized, the sludge organisms are alive even though they may be metabolizing at a reduced rate. There may be several explanations if no oxygen is utilized. One, the organisms are dead; either the material was lethal or the organisms were not capable of using the material in their metabolic processes. Or two, there may be a lag period during which the material is unavailable to the organisms.

In studies where a food source in addition to the material being tested was present, the utilization or lack of utilization of oxygen has more well-defined interpretations. If oxygen is utilized at any rate, then the organisms are not dead even though their metabolism may be depressed. If the oxygen uptake rate exceeds that of the control units, then the material is not merely stimulatory but acts as an additional food source which is readily available and is being utilized. If the oxygen uptake rate is the same as the rate of the control (i.e., only sludge organisms and food) the organisms did not utilize the material nor did it affect them; the material likely will pass through the treatment plant. If the oxygen uptake rate is zero, the material probably is lethal.

Where the authors of the literature sources provided sufficient background data, attempts were made to determine whether the material being studied was lethal or resistant to biodegradation.

It is common practice to refer to a metallic ion by the name of the metal rather than by the name of the ion, e.g., Fe^{+2} is generally called iron rather than ferrous iron. The common practice has been followed in this handbook. Nevertheless, all metals are in an ionic form by the designation EL in column 3. The particular ion studied is given in parentheses in column 1 when it was specified in the literature. The concentrations of metallic compounds should be assumed to be given as the element, e.g., 10 mg/l chromate as chromium, unless specified otherwise in column 11.

TABLE 1

CODING SHEET FOR: CLASSIFICATION OF CHEMICAL
(Columns 2 through 4 of the EFFECTS MATRIX)

AC - Strong Acid
AMP - Amphoteric
AN - Anion
AR - Aromatic Hydrocarbon
BA - Strong Base
CA - Cation
CN - Organic Compound containing Nitrogen
CO - Organic Compound contianing Oxygen
CP - Organic Compound containing Phosphorus
CS - Organic Compound containing Sulfur
CX - Organic Compound containing Halogen
EL - Element
Gas - Gas
HC - Unsubstituted Hydrocarbon
HM - Heavy Metal or containing Heavy Metal
IN - Inorganic Compound
NAR - Non-aromatic Hydrocarbon
NMC - Non-metallic Compound
OR - Organic Compound
RAS - Radioactive Substance
SA - Anionic and Cationic Compounds containing the element exist
SHC - Substituted Hydrocarbon
ST - Salt of Organic Compound
WA - Weak Acid
WB - Weak Base

TABLE 2

CODING SHEET FOR: NATURE OF CHEMICAL
(Column 5 of the EFFECTS MATRIX)

01 - Elements (Selected metals, etc. Essentially water inert)
02 - Selected Minerals (Essentially insoluble and inert in water, including oxides, phosphates, silicates, sulfates, sulfides)
03 - Salts (Low and medium atomic weight elements, mostly soluble, low toxicity, neutral)
04 - Salts (Low and medium atomic weight elements, mostly lower solubility, hydrolyzed or oxidizers/reducers, low to medium toxicity, including some organic anions)
05 - Salts (Heavy metal-containing, mostly soluble, somewhat toxic)
06 - Acids (Mineral, strong organic, acid oxides, etc.)
07 - Short Chain Organic Acids
08 - Long Chain and Cyclic Organic Acids
09 - Caustics, Alkalies, Bases, etc.
10 - Oxides (Heavy metal - also some carbonates, sulfides, phosphates)
11 - Insecticides, Herbicides, Fungicides and Rodenticides
12 - Phenols and Cresols
13 - Poisons (Metal-containing)
14 - Poisons (Halogenated hydrocarbons)
15 - Poisons (Metal-free and halogen-free; essentially organic)
16 - Radioactive Materials
17 - Heavy Metal Organics
18 - Flammable Hydrocarbons
19 - Non-flammable Hydrocarbons
20 - Flammable Hydrocarbon Derivatives
21 - Non-flammable Hydrocarbon Derivatives
22 - Compressed Gases
23 - Miscellaneous and Special Materials

TABLE 3

CODING SHEET FOR: PROCESS OPERATING PARAMETERS AND VARIABLES
(Column 8 of the EFFECTS MATRIX)

Refer to: Glossary, Water and Wastewater Control Engineering, Joint editorial board of APHA, ASCE, AWWA, AND WPCF, 1969, for additional terms and explanations.

BOD - Biochemical Oxygen Demand
CD - Chlorine Demand
COD - Chemical Oxygen Demand
CR - Chemical Removal
DE - Dehydrogenase Enzyme Activity
DO - Dissolved Oxygen
DT - Detention Time
G - General System Operation
HRT - Hydraulic Retention Time
M - Change in Metal Toxicity
MI - Micro-organism Population
N - Nitrification
NB - Nutrient Balance
OT - Oxygen Transfer*
OU - Oxygen Uptake
pH - Negative Logarithm of the Hydrogen Ion Concentration
SAND - Sludge-Digested
SDI - Sludge Density Index
SF - Sludge Filterability
SMC - Sludge Metal Content
SO - Sludge Oxidation
SP - Sludge Production
SS - Suspended Solids
SSR - Solids Settling Rate
SVI - Sludge Volume Index
T - Turbidity
TP - Temperature
VSS - Volatile Suspended Solids

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*With regard to the rate of oxygen transfer:

$\alpha = K_L a$ (waste)/$K_L a$ (water)
$\beta = C_S$(waste)/C_S(water)
where $K_L a$ = oxygen transfer coefficient
C_S = saturation concentration of oxygen

TABLE 4

CODING SHEET FOR: CONDITIONS OF THE STUDY
(Column 10 of the EFFECTS MATRIX)

1. Type of Waste
    - 1a. Industrial
    - 1b. Domestic
    - 1c. Industrial - Domestic
    - 1d. Synthetic

2. Hazardous Material Laoding Conditions
    - 2g. Continuous
    - 2h. Slug dose
    - 2i. Not Controlled
    - 2j. Initial Dose Only
    - 2k. Batch
    - 2l. Semi-Continuous

3. Type of Organisms
    - 3k. Pure Culture - Bacteria
    - 3l. Sewage Organisms - Aerobic
    - 3m. Sewage Organisms - Anaerobic
    - 3o. Pure Culture - Fungus
    - 3p. Acclimated
    - 3q. Unacclimated

4. Scale of Study
    - 4a. Bench
    - 4b. Pilot Plant
    - 4c. Full Scale
    - 4d. Repirometer
    - 4e. BOD Bottle

5. Variables that were observed
    - 5a. pH
    - 5b. BOD
    - 5c. COD
    - 5d. Dissolved Oxygen
    - 5e. Aeration Time
    - 5f. Nutrient Balance
    - 5g. Oxygen Uptake Rate
    - 5h. Solids Concentration
    - 5i. Temperature
    - 5j. Turbidity
    - 5k. Flow Rate
    - 5l. Sludge Volume Index
    - 5m. Gas Production
    - 5n. Nitrogen
    - 5p. Total Oxygen Demand
    - 5r. Total Carbon
    - 5s. Alkalinity
    - 5t. Theoretical Oxygen Demand (TOD)
    - 5u. Color
    - 5z. Zeta Potential

6a. Results of Literature Review

7a. Characteristics of Industrial Discharge

SECTION VI

SUMMARY OF HAZARDOUS MATERIAL EFFECTS

This section is a concise summary of the extensive information presented in the "HAZARDOUS MATERIALS EFFECTS MATRIX" (Section VII). Materials are arranged in alphabetical order with brief remarks to summarize the information in the literature.

Throughout this summary and the EFFECTS MATRIX, the preferred or generic names of materials are used wherever possible; occasionally, however, registered trademarks are reported. Registered trademarks are marked with an®. While the authors have attempted to avoid this practice, the trade name often is the most familiar identifier and thus is used to assure utility of this handbook: use of the trade names as mentioned above, in no way indicates that the author or the Environmental Protection Agency endorses or recommends that material. The intent merely is to document technical information available in the literature.

Many materials are known by several names. Alternate names and generic names of materials commonly known by trade names can be found in chemical handbooks such as the Merck Chemical Index.

A significant conclusion reached from the critical evaluation of the large volume of technical data is that there is little definitive information on the number and frequency of treatment plant upsets and, particularly, on the actual causes of the failures of the plants to meet permit standards. Too few "post mortems" are either undertaken or reported.

Note: The names of chemicals beginning with "Di-", "Tri-", "Bis-", etc. are generally indexed under "D", "T", and "B", respectively. Chemical names requiring a stereochemical prefix (n = normal, s = sec = secondary, D = dextrorotatory, o = ortho, m = meta, etc.) are indexed under the name of the chemical without the prefix, e.g., "sec-Butylbenzene" is indexed under "B". In some cases--chiefly because of common usage--esters are indexed under the name of the alcohol, e.g., "n-Butyl ester of 2,4,5-T" is indexed under "B", and some salts are indexed under the name of the cation, e.g., "Sodium alkyl sulfonate" is indexed under "S". Chemical names beginning with a number or a Greek letter ("beta") are indexed under the first letter of the name of the chemical, e.g., "beta-Propiolactone" is indexed under "P". Users are advised to check for chemicals under several potential alphabetical listings. Because of its inherent complexity, the inclusion of a cross-index was eliminated from this report.

Acetaldehyde ----- Chemical removal by biological treatment was 70 to 95%.

Acetone ----------- Chemical removal by aerated lagoon treatment was 10 to 30%.

Acetonitrile ------ O_2 consumption was inhibited by 490 mg/l of chemical; 50 to 70 mg/l reduced efficiency to the threshhold of poor performance. Chemical removal was poor.

Acetylglycine ----- At 500 mg/l the chemical was readily and rapidly oxydized.

Acrylic Acid ------ Chemical removal in completely mixed activated sludge was 85 to 95%. Oxygen transfer rate coefficient was not affected.

Acrylonitrile ----- Chemical removal by biological treatment was 70 to 100%. Oxygen transfer rate coefficient was not affected by up to 50 mg/l of chemical.

Adipic Acid ------- At 500 mg/l influent concentration, rapid oxidation occurred. 7% of TOD was exerted after 24 hours.

Alanine ----------- Stimulated O_2 consumption at 500 mg/l influent concentration with up to 40% of TOD exerted in 24 hours; alanine was oxidized readily.

Alcohols ---------- Removal of various alcohols generally was high ranging from 40 to 85%; 30% resulted from oxidation and the remainder by conversion to protoplasm.

Aldrin ® --------- Chemical was not significantly degraded.

Alkyl Benzene Sulfonates ------ At 100 ppm influent concentration, n-dodecyl ABS is not resistant to biodegradation; O_2 utilization was lower for keryl ABS and tetrapropenyl ABS.

Amines ------------ Aliphatic amines inhibited O_2 uptake; sludges did not acclimate to rapid oxidation of amines.

Amino Acids ------- Influent concentration of 500 to 1000 mg/l resulted in 40% (mean) oxidation of amino acids.

Aminotriazole ----- There was no significant biodegradation of chemical.

n-Amyl Alcohol ----	Toxic threshhold for aquatic organisms was approximately 350 mg/l.
sec-Amylbenzene ---	500 mg/l concentration toxic during 24 hours of aeration.
tert-Amylbenzene --	500 mg/l concentration toxic during 24 hours of aeration.
Aniline -----------	At concentrations of 10 and 20 mg/l, the increased chemical concentrations increased chlorine demand. At 500 mg/l, toxic and inhibiting effects were exhibited for up to 72 hours.
Anthracene --------	At 500 mg/l a lag period of up to 24 hours may occur before sludge acclimation and slow oxidation of the chemical.
Barium ------------	Greater than 100 mg/l inhibited O_2 consumption.
Benzaldehyde ------	At 500 mg/l chemical was oxidized slowly for 6 hours; oxidation increased between 24 and 72 hours with 60% of TOD exerted after 144 hours. A 4% solution was toxic.
Benzamide ---------	At 500 mg/l chemical undergoes slow oxidation for first 6 hours, then rapid oxidation from 24 to 72 hours with 60% TOD exerted after 144 hours.
1,2-Benzanthracene-	At 500 mg/l chemical was very slowly oxidized with 2% of TOD exerted in 144 hours.
Benzene -----------	Benzene concentrations of 50 to 500 mg/l had little affect on BOD removal efficiency. Completely mixed activated sludge achieved almost complete removal of up to 35 mg/l benzene.
Benzene Sulfonic Acid ------------	At 500 mg/l chemical was readily, but slowly, oxidized with 60% of TOD exerted after 144 hours.
Benzenethiol ------	At 500 mg/l the chemical inhibited O_2 uptake for up to 144 hours of oxidation.

Benzidine -------- Chemical inhibited O_2 uptake for 144 hours of oxidation at 500 mg/l initial concentration.

Benzonitrile ----- Toxic or inhibitory effects exhibited for first 72 hours of oxidation with up to 40% TOD exerted after 144 hours; sludge acclimation was noted.

3,4-Benzpyrene --- Chemical was readily, but slowly, oxidized at 500 mg/l influent concentration; up to 6% of TOD exerted after 144 hours of oxidation.

Benzylamine ------ Chemical inhibited O_2 uptake for up to 144 hours at 500 mg/l initial concentration.

4,4'-Bis
(dimethylamino)
benzophenone ----- At 500 mg/l lag periods of up to 72 hr. were experienced before slow oxidation began.

Boron (borates)--- Boron concentrations of 0.05 to 10 mg/l produced inhibition of activated sludge process.

Butanamide ------- At 500 mg/l the chemical was readily, but slowly, oxidized for 24 hours.

Butanedinitrile -- While 500 mg/l of the chemical was reported to be toxic for up to 72 hours of oxidation, a similar concentration was readily, but slowly, oxidized in 24 hr.

Butanenitrile ---- At 500 mg/l butanenitrile reportedly both inhibited O_2 consumption for 24 hr. and was readily, but slowly, degraded with rapid oxidation in first 6 hr.

Butanol ---------- 80% BOD removal for complete mixed activated sludge with concomitant 98% removal of Butanol.

Butylbenzenes ---- Not susceptible to biodegradation at 100 mg/l initial concentration.

sec-Butylbenzene - 500 mg/l was toxic during 24 hours aeration.

tert-Butylbenzene- 500 mg/l was toxic during 24 hours of aeration.

n-Butyl ester
of 2,4,5-T --- Herbicide was degradable with 20% of measured COD exerted.

2,3-Butylene
Oxide ----------- Chemical was degraded very slowly at 500 mg/l initial concentration.

Butyric Acid ------ At 500 mg/l the chemical was rapidly oxidized.

Cadmium ----------- Between 1 and 10 mg/l significantly inhibits O_2 consumption.

Cadmium-Manganese
Mixture --------- Mixture was more inhibitory than a similar concentration of the individual elements.

Cadmium-Zinc
Mixture --------- Mixture was more inhibitory than a similar concentration of the individual elements.

Calcium Gluconate - At 250 mg/l chemical was susceptible to biodegradation but inhibited O_2 consumption.

Captan® --------- Fungicide was not degradable.

Chlorates --------- Greater than 10 mg/l chlorates significantly inhibited O_2 consumption.

Chloranil --------- At 10 mg/l the chemical inhibited O_2 consumption.

Chlordane --------- Insecticide was only slightly degraded.

Chlorine ---------- At 200 and 500 mg/l chlorine detrimentally affected sludge filterability.

4-Chloro-3-methyl-
phenol ---------- At 10 mg/l the chemical was mildly inhibitory; 100 mg/l was toxic.

Chromium ---------- A 10 mg/l slug dose of chromium had little affect on activated sludge process, but nitrification was inhibited. Large amounts of chromium immobilized in sludge. A 500 mg/l slug dose of 4 hr. duration significantly affected system; recovery time was 4 days. Hexavalent chromium was more toxic than trivalent chromium. (See p.59).

Chromium-Copper
Mixture --------- Mixture was slightly more toxic than was copper alone, but significantly more toxic than was chromium alone.

Chromium-Iron
Mixture --------- Mixture was more toxic than either element indi-

vidually.

Citric Acid ------- Chemical was biodegradable but depressed O_2 consumption.

Copper ------------ A 30 mg/l slug dose caused a detrimental effect on activated sludge organic removal efficiency with recovery in 24 hr.; a 75 mg/l, 4 hr. duration slug caused a 24 hr. effect. Copper removal generally was good with large amounts found in the sludge. As organic loading increased copper removal decreased.

Copper-Chromium Mixture --------- Mixture was slightly more toxic than was copper alone and significantly more toxic than was chromate alone.

Copper-Cyanide Mixture --------- Mixture was more toxic than was copper alone, but less toxic than was cyanide alone.

Copper-Iron Mixture --------- Mixture was more toxic than was copper alone, but less toxic than was iron alone.

Copper-Nickel Mixture --------- Mixture was more toxic than was either metal individually.

m-Cresol ---------- Chemical was biodegradable at 10 and 20 mg/l. Increased chemical concentrations (10 to 20 mg/l) resulted in decreased chlorine demand.

Crotonaldehyde ---- In excess of 90% chemical removal by biological systems.

Cyanide ----------- Activated sludge recovered from 40 mg/l slug dose in 2 days.

Cystine ----------- At 1000 mg/l concentration, O_2 consumption was completely inhibited and solids production stopped.

L-Cystine --------- At 500 mg/l chemical was readily, but slowly, oxidized.

DDT -------------------- Insecticide was not significantly degraded.

Diazinon® -------------- Insecticide was not significantly degraded.

Dibenzacridine --------- Chemical was slowly degraded at initial concentration of 500 mg/l; a lag period of 6 hr. was demonstrated.

1,2,5,6-Dibenzanthracene------ Chemical was slightly inhibitory but slowly oxidized at 500 mg/l initial concentration; up to 8% TOD exerted after 144 hours.

2,4-and 2,6-Dichlorophenol ------- Chemical removals greater than 98% were achieved after five days of aeration. Initial chemical concentrations were 60 ppm.

2,4-Dichlorophenoxyacetic Acid ----------------- (2,4 - D) Greater than 98% removal was achieved after five days aeration at 170 mg/l influent concentration.

2,6-Dichlorophenoxyacetic Acid ----------------- (2,6 - D) At 180 mg/l influent concentration, 30% removal was measured during the fourth day of aeration, after a 3-day lag.

2,4-Dichlorophenoxypropionic Acid ---- No significant decrease of 190 mg/l initial concentration after seven days of aeration.

Dieldrin --------------- Insecticide was not significantly degraded.

Di(2-ethylhexyl)-phthalate ------------ Biological systems achieved greater than 50% removal of chemical; O_2 transfer rate coefficient was not significantly affected at 1 and 10 mg/l of chemical.

α,α'-Diethylstilbenediol --------- Chemical demonstrated inhibitory effects at 500 mg/l concentration.

Dimethylamine ---------- Increased chemical concentration (20 to 100 mg/l) resulted in increased chlorine demand.

9,10-Dimethylanthracene ----------- Chemical was not toxic but oxidation was slow at 500 mg/l initial concentration.

7,9-Dimethylbenz(c)-
acridine -------- At 500 mg/l, two out of three sludges showed toxic effects; the other slowly oxidized the chemical; 4% TOD exerted after 144 hours.

7,10-Dimethylbenz(c)-
acridine -------- At 500 mg/l the chemical was toxic.

9,10-Dimethyl-1,2-
benzanthracene -- At 500 mg/l chemical was readily, but slowly, oxidized with up to 13% TOD exerted after 144 hours.

2,4-Dinitrophenol - Chemical concentrations of 1 and 5 mg/l reduced the O_2 uptake rate and solids production; greater than 15 hr. aeration required for 90% COD removal.

2,4-D,isooctyl
ester ----------- Pesticide was materially degraded.

Dulcitol ---------- Chemical was slightly inhibitory in a 2% solution.

Endrin ------------ Insecticide was not significantly degraded.

Erucic Acid ------- At 500 mg/l the chemical was degraded with 10% TOD exerted after 24 hours of oxidation.

1,2-Ethanediol ---- At 500 mg/l a 1 to 3 hr. lag resulted before oxidation began. O_2 consumption was significantly depressed.

Ethanol ----------- Readily degradable at concentrations up to 1000 mg/l with up to 95% removal.

Ethyl Acetate ----- Greater than 90% removal was achieved by biological systems.

Ethyl Acrylate ---- Greater than 90% removal was achieved by biological systems.

Ethyl Benzene ----- Greater than 90% removal was achieved by biological systems.

Ethyl Butanol ----- Greater than 90% removal achieved by completely mixed activated sludge.

2-Ethylhexyl-
acrylate -------- Greater than 90% removal by biological systems.

Ferbam® ----------- Fungicide was materially degraded.

2-Fluorenamine ---- At 500 mg/l chemical was slowly oxidized, but inhibitory.

N-2-Fluorenyl Acetamide ------- At 500 mg/l chemical was oxidized slowly with 12% TOD exerted after 144 hours.

Fluoride ---------- At 30 mg/l there was no chemical removal by an aerated lagoon.

Formaldehyde ------ Chemical concentrations of from 50 to 720 mg/l demonstrated lag periods greater than 2 days before oxidation began. Following acclimation, 95% removal was achieved at 1750 mg/l initial formaldehyde concentration. By buffering with $NaHCO_3$ formaldehyde concentrations of up to 1500 mg/l were only slightly inhibitory.

Formamide --------- At 500 mg/l the chemical was readily, but slowly, oxidized.

Formic Acid ------- At 720 mg/l chemical concentration O_2 consumption was slightly stimulated.

Fumaric Acid ------ A 1/120 N solution slightly stimulated O_2 consumption.

Glutamic Acid ----- At 500 mg/l chemical was readily oxidized.

Glycerine --------- At 720 mg/l chemical stimulated O_2 consumption.

Glycine ----------- At 720 mg/l chemical stimulated O_2 consumption.

Grease ------------ 74% removal of grease in secondary treatment.

Heptachlor -------- Insecticide was slightly degraded.

n-Heptane --------- Greater than 90% removal by biological systems.

1-Hexanol --------- Greater than 70% removal by biological systems.

Hydracrylonitrile - Less than 10% removal achieved in aerated lagoon.

Hydrogen Cyanide -- A 500 mg/l concentration was toxic for 72-hour oxidation period.

Hydrogen Ion ------ Best results were achieved in the neutral pH range.

Hydrogen Sulfide -- Chemical volatilizes and becomes corrosive.

4-Hydroxybenzene-
carbonitrile ---- At 500 mg/l chemical was toxic for up to 72 hour.

Iodine ------------ Chemical was inhibitory at concentrations greater than 10 mg/l.

Iron, Ferrous ----- Inhibited O_2 uptake at concentrations greater than 100 mg/l.

Iron, Ferric ------ Inhibited O_2 uptake at concentrations greater than 100 mg/l.

Iron-Chromium
Mixture --------- Mixture was more toxic than individual elements.

Iron-Copper
Mixture --------- Mixture was more toxic than iron and less toxic than copper.

Isopropanol ------- Greater than 70% removal of chemical by biological systems.

Isopropyl Ether --- Greater than 70% removal of chemical by biological systems.

Lactic Acid ------- At 720 mg/l chemical greatly stimulated O_2 consumption.

Lactonitrile ------ System unable to handle concentrations greater than 140 mg/l without acclimation.

Lauric Acid ------- Surfactant forms were readily oxidized.

Lead -------------- Concentrations greater than 10 mg/l caused inhibitory effects.

Lindane ----------- Insecticide was not significantly degraded.

Malathion --------- Insecticide was not significantly degraded.

Malic Acid -------- A 1/120 N solution stimulated O_2 consumption.

L and DL Malic
Acid ------------ At 500 mg/l the chemicals were oxidized but a lag period of greater than 8 hr. was indicated.

Malonic Acid ------ At 500 mg/l the chemical inhibited O_2 uptake. A 1/120 N solution stimulated O_2 uptake.

Maneb® ----------- Fungicide was materially degraded.

Manganese --------- Approximately 10 mg/l caused inhibition of O_2 uptake by activated sludge.

Manganese - Cadmium Mixture - Concentration of 100 mg/l manganese and 10 mg/l cadmium was more inhibitory than either element alone.

Manganese - Zinc Mixture ---- Mixture was more inhibitory than either element alone.

Mercury ----------- Chemical demonstrated inhibition at 1 mg/l and toxicity at 200 mg/l in one study. In another study it was toxic or inhibitory at concentrations greater than 5 mg/l. Mercury was removed by uptake in sludge.

Methanol ---------- Chemical could be removed by biological systems, but at 500 mg/l a 3 to 5 hr. lag period was indicated before oxidation commenced. At 1000 mg/l O_2 uptake was severely depressed.

7-Methyl-1,2-benzanthracene -- At 500 mg/l chemical inhibited O_2 uptake for at least 24 hours.

Methyl Benzene Carbonitrile ---- At 500 mg/l the chemical was toxic for up to 72 hours.

20-Methyl-cholanthrene ---- At 500 mg/l the chemical showed inhibitory effect but could be slowly oxidized.

Methylethyl-pyridine -------- Less than 30% removal achieved by aerated lagoon treatment.

Methyl Parathion -- Insecticide was not significantly degraded.

2-Napthylamine ---- A 500 mg/l concentration was toxic.

Naphthalene ------- Greater than 70% removal achieved by biological systems. However, at 500 mg/l a lag period of up to 24 hr. was indicated.

Nickel ------------ Greater than 5 mg/l continuous dose significantly reduces efficiency of biological systems. A 200 mg/l, 4 hr. slug dose produced a 24 hr. effect with 40 hr. necessary for recovery. Activated sludge removal of nickel was poor but was improved by lime addition.

Nickel-Copper Mixture --------- Mixture was more toxic than either element individually.

Nickel-Cyanide Mixture --------- Mixture was more toxic than was nickel alone but less toxic than was cyanide alone.

Nitrilotriacetate (NTA) ----------- No effect up to 200 mg/l slug dose, but acclimation required for removal. (See Trisodium nitrilotriacetate)

Nitrite ----------- Concentrations greater than 10 mg/l inhibited O_2 uptake.

Nitrobenzene ------ At 500 mg/l chemical was toxic, inhibiting O_2 uptake for 144 hours.

2-Nitrofluorene --- At 500 mg/l chemical was slowly oxidizable.

Octyl Alcohol ----- 75 to 85% removal achieved by completely mixed activated sludge with little effect on O_2 transfer.

p,tert-Octyl-phenoxy-nonaethoxy-ethanol --------- At 5 and 10 mg/l extended aeration achieved greater than 90% removal with no significant problems except that sludge production increased.

Oil, crankcase----- At 230 mg/l crankcase oil exhibited an O_2 uptake slightly less than that of the control with BOD removal efficiency of about 93%.

Oil, crude -------- At 80 mg/l crude oil exhibited O_2 uptake equivalent to control.

Oil, mineral ------ At 1000 mg/l mineral oil greatly inhibited O_2 consumption after 24 hours.

Oil, olive -------- At 900 mg/l olive oil inhibited O_2 uptake by one-third to one-half that of the control.

Oil, refinery ----- At 90 mg/l refinery oil exhibited a 44% greater O_2 uptake rate than the control with 94% BOD removal.

Oil, vegetable ---- At 150 mg/l vegetable oil exhibited a 30% greater O_2 uptake than the control with BOD removal of about 94%.

Oleic Acid -------- A 1/120 N solution inhibited O_2 uptake.

Organic Acids ----- At 250 to 720 mg/l organic acids were removed primarily by oxidation.

Oxalic Acid ------- At 250 to 720 mg/l O_2 consumption was significantly inhibited.

Oxydiproprionitrile- 170 mg/l did not affect biological system performance but acclimation was necessary.

Paraldehyde ------- 30% removal of chemical by aerated lagoon treatment.

Parathion --------- Insecticide was not significantly degraded.

Pentachlorophenol - At 150 mg/l chemical inhibited O_2 uptake and was not significantly degraded.

Pentaerythritol --- No toxic effect up to 1000 mg/l concentration at pH 7.0.

Pentamethylbenzene --------- At 500 mg/l chemical was toxic or inhibitory during initial 24 hours of aeration.

Pentanamide ------- At 500 mg/l chemical was readily but slowly oxidized with 14% TOD exerted after 24 hours.

Pentane ----------- At 500 mg/l pentane was resistant or very slowly oxidized.

Pentanedinitrile -- At 500 mg/l chemical was toxic or very slowly oxidized.

Pentanenitrile ---- At 500 mg/l chemical could be slowly oxidized.

Peptone ----------- At 720 mg/l of peptone O_2 uptake was stimulated and greater than 90% BOD removal was achieved.

Phenanthrene ------ At 500 mg/l the chemical was slowly oxidized with 45% of TOD exerted after 144 hours.

Phenol ------------ Although phenol was inhibitory without acclimation; acclimated biological systems could achieve almost complete phenol removal.

p-Phenylazoaniline- Chemical was inhibitory at 500 mg/l.

p-Phenylazophenol - Chemical was inhibitory at 500 mg/l; small degree of biological oxidation after a lag period.

(m-, p-, and o-) Phenylenediamine- At 500 mg/l chemicals were toxic during 24 hours aeration.

Phenyl Methyl Carbinol -------- Greater than 85% removal was achieved by completely mixed activated sludge.

Polyethoxyethanol - At 100 mg/l the synthetic detergent was readily biodegradable.

Polyethoxy Fatty Ester ----------- At 100 mg/l the synthetic detergent resisted biodegradation.

Potassium Cyanide - At 480 mg/l chemical completely inhibited O_2 consumption.

Propanedinitrile -- At 500 mg/l chemical was toxic for up to 72 hours of oxidation.

Propanenitrile ---- At 500 mg/l the chemical was toxic for at least 72 hr.

β-Propiolactone --- At 500 mg/l chemical resisted biological oxidation for up to 144 hour.

n-Propylbenzene --- At 37.5 mg/l chemical could be oxidized biologically but depressed O_2 uptake. One of the more toxic benzene derivatives.

Sodium Alkylbenzene Sulfonate ------- Surfactant was susceptible to bio-oxidation after extended periods.

Sodium Alkyl Sulfonate ------- Surfactant was susceptible to bio-oxidation after extended periods.

Sodium Aluminate -- Produced a more readily dewatered sludge.

Sodium Lauryl Sulfate --------- Surfactant was readily degraded after extended periods.

Sodium N- Oleyl-N-
Methyl Taurate -- Surfactant was readily degraded after extended periods.

Sodium
Pentachlorophenol-Slug doses greater than 20 mg/l drastically affected performance of biological systems; chemical was not removed and sludge would not settle. Systems could be acclimated to chemical. (See pentachlorophenol).

Sodium α-Sulfo
Methyl Myristate- Surfactant was readily degraded after extended periods.

Styrene ----------- Greater than 95% removal by completely mixed activated sludge.

Sulfate ---------- Greater than 300 mg/l of sulfate corroded concrete even at neutral pH.

Sulfide ----------- Chemical was slightly inhibitory at 25 mg/l.

Sulfite ----------- Up to 500 mg/l can be oxidized if system is acclimated, but increased oxygen required.

Surfactants,
Nonionic -------- Greater biodegradation of nonionic surfactants than anionic surfactants.

Tannic Acid ------- A 1/120 N solution inhibited O_2 consumption.

Tetraethyl
Pyrophosphate --- Insecticide not significantly degraded.

1,2,4,5-
Tetramethyl-
benzene --------- After a 3 hr. lag period the chemical was degraded slightly at 500 mg/l.

Thanite®---------- Insecticide was materially degraded.

Thioacetamide ----- O_2 uptake was completely inhibited at 1000 mg/l concentration.

Thiocyanate ------- 1000 mg/l concentration significantly inhibited O_2 consumption.

Thioglycolic Acid - At 650 mg/l chemical was toxic or resistant to biodegradation.

2-Thiouracil ------ At 500 mg/l chemical was slowly but readily oxidized.

Thiourea ---------- At 500 mg/l thiourea inhibited O_2 uptake for up to 144 hours.

Toluene ----------- Greater than 90% removal was achieved by activated sludge; but at 500 mg/l toluene oxidation periods longer than 24 hr. were required.

o-, m-, and p-Toluidine --------- At 500 mg/l m- and p- Toluidine were slightly oxidized while o-Toluidine was toxic.

2,4,6-Trichloroaniline ------ Up to 10 mg/l of chemical was not inhibitory.

2,4,5-Trichlorophenol ---------- Pesticide was slightly degraded.

2,4,6-Trichlorophenol ---------- Significant inhibition occurred between 10 and 50 mg/l of chemical.

2,4,5-Trichlorophenoxy-acetic Acid ------------ (2,4,5-T) At up to 75 mg/l chemical was materially degraded; at 150 mg/l chemical was slightly degraded.

2,4,6-Trichlorophenoxy-acetic Acid ------------ (2,4,6-T) At 50 mg/l greater than 50% chemical removal was achieved during 14 days of aeration.

2,4,5-Trichlorophenoxy-propionic Acid ------------ At 100 mg/l after a 2 day lag greater than 95% chemical removal was achieved in 17 days.

1,2,4-Trimethylbenzene --------- Toxic at 500 mg/l for at least 18 hours of aeration, after which the material was slightly oxidized.

2,4,6-Trinitrotoluene ------- (TNT) Greater than 50% removal for concentration of 5 to 25 mg/l and retention times of 3 to 14 hr.

Trisodium Nitrilotriacetate ----- (NTA) At up to 200 mg/l the chemical did not upset the activated sludge process; in 3 to 6 hr. degradation by acclimated sludge of up 500 mg/l was complete.

Tyrosine ---------- At 500 mg/l chemical stimulated O_2 uptake after a 3 to 5 hr. lag.

Urea -------------- O_2 consumption inhibited by urea concentrations up to 720 mg/l.

Urethane ---------- Chemical completely inhibited O_2 consumption.

Xylene ------------ A 500 mg/l concentration was toxic for the first 24 hour aeration.

Zinc -------------- The lowest continuous dose which caused an effect was 10 mg/l. At this concentration 89% Zinc removal was achieved, primarily by adsorption of Zinc to activated sludge. The lowest 4 hr. slug dose to cause a 24 hr. effect was 160 mg/l.

Zinc-Cadmium Mixture --------- Mixture was more toxic than either element alone.

Zinc-Manganese Mixture --------- Mixture was more toxic than either element alone.

Zineb®------------ Insecticide was slowly degraded with 5 to 20% of COD exerted.

Ziram®------------ Insecticide was slowly degraded with 5 to 20% of COD exerted.

SECTION VII

HAZARDOUS MATERIALS EFFECTS MATRIX

The user of this matrix is urged to study Section III carefully before he attempts to decode the information provided. The user should also take note of the comments on page 16 and, indeed, may find it advantageous to make copies of pages 9, 12, 13, 14, and 15 for "at-hand" use with the matrix. The references cited in Column 12 are listed numerically starting on page 184, "References."

1	2	3	4	5	6	7	8	9	10	11	12
Acetaldehyde	OR	SHC NAR	CO	20		70% to 90%			1a,2i 31,4c 5a,5b 5c,5d 5e,5h 5i,5k	Aerated lagoon treatment .	9*
Acetaldehyde	OR	SHC NAR	CO	20		85% to 95%			1a,2i 31,4c 5b,5d 5e,5g 5h,5i 5k	Completely mixed activated sludge process.	33*
Acetone	OR	SHC NAR	CO	20		10% to 30%			1a,2i 31,4c 5a,5b 5c,5d 5e,5h 5i,5k	Aerated lagoon treatment.	9+
Acetone	OR	SHC NAR	CO	20					1d,2j 31,3p 4a 5e,5g	Acetone completely degraded or lost by stripping. No identifiable degradation product.	47+

*Refer also to Reference No. 15 and 42
+Refer also to Reference No. 42

1	2	3	4	5	6	7	8	9	10	11	12
Acetonitrile	OR	SHC NAR	CN	20	490 mg/l		SVI	61.0	2j 31 3k 4a 5a 5b 5e 5g 5h 51 5t	Inhibited any oxygen consumption in units fed with chemical. As material was sole source of carbon or energy, material may have been resistant to biodegradation or toxic.	52
							pH	Decreased from 7.0 to 6.7 during 24 hr. of aeration.			
							SS	No significant change after 24 hr. of aeration.			
							OU	Oxygen consumption was totally inhibited for 24 hr. None of TOD was exerted in 24 hr.			
Acetonitrile	OR	SHC NAR	CN	20	88 mg/l		CR	55% of influent nitrogen as nitrile resulted in effluent containing 70% oxidized nitrogen (NO_2 and NO_3).	1d,21 31,3p 4a,5a 5b,5c 5h,5i 5k,5n 5t	Acclimation period required for chemical removal. Sludge floc was highly dispersed.	41
					143 to 165 mg/l		CR	Poor.			
							G	Threshold of poor performance.			

1	2	3	4	5	6	7	8	9	10	11	12
Acetonitrile	OR	SHC NAR	CN	20	500 mg/l		OU	Toxic or inhibitory during oxidation periods up to 72 hr. 1.4% of TOD was exerted in 72 hr.	1b,2j 3l,3p 3q,4d 5e,5g 5h,5i 5t	Mononitrile compound. Refractory nature decreases with increasing chain length. Monocarboxylic acid having same number of carbon atoms (ethanoic or acetic acid) showed up to 44.5% of TOD exerted after 72 hr. of oxidation.	43
Acetylglycine (N-Acetyl-2-aminoethanoic acid)	OR AMP	SHC NAR	CO CN	07	500 mg/l		OU	Readily and rapidly oxidized with 9.3% of TOD exerted after 6 hr. and 18.5% after 24 hr. of oxidation. In 2 cases oxygen uptake continuously increased during 24 hr. study; however, in 1 case, oxygen consumption increased for first 2 hr. then decreased until 17 hr. after which it increased again.	1b 2j 3l 3q 4d 5e 5g 5h 5t		49

1	2	3	4	5	6	7	8	9	10	11	12
Acrylic Acid	OR WA	SHC NAR	CO	07		50% to 70%			1a,2i 31,4c 5a,5b 5c,5d 5e,5h 5i,5k	Aerated lagoon treatment	9
Acrylic Acid	OR WA	SHC NAR	CO	07		85% to 95%	OT	α value for 1 mg/1 acrylic acid is 1.00; and for 10 mg/1,α =0.98.	1a,2i 31,4c 5b,5d 5e,5g 5h,5i 5k	Completely mixed activated sludge process.	33
Acrylo-nitrile	OR	SHC NAR	CN	20		70% to 90%			1a,2i 31,4c 5a,5b 5c,5d 5e,5h 5i,5k	Aerated lagoon treatment.	9*
Acrylo-nitrile	OR	SHC NAR	CN	20		95% to 100%	OT	α value for 10 mg/1 and 50 mg/1 of acrylonitrile is 1.10.	1a,2i 31,4c 5b,5d 5e,5g 5h,5i 5k	Completely mixed activated sludge process.	33*
Acrylo-nitrile Plant Wastewater				20			CR	95 to 99% cyanide removal at cyanide loadings of 0.2 to 0.25 kg/m^3/day after sludge acclimated 2 to 3 weeks.		Wastewater contained lactonitrile or acrylonitrile. Cyanide concentration- 1000 ppm; O_2 demand - 6750 ppm.	20

*Refer to Reference No. 41 for data collected under semi-continuous loading conditions.

1	2	3	4	5	6	7	8	9	10	11	12
Adipic Acid (Hexanedioic Acid)	OR WA	SHC NAR	CO	08	500 mg/l		OU	Rapidly, and readily oxidized. After 24 hr. of oxidation, 7.1% of TOD exerted.	1b,2j 31,3q 4d,5e 5g,5h 5t	After 6 hr. and 12 hr. 1.3% of TOD exerted. Oxidation improved greatly after 12 hrs.	49
Alanine	OR AMP	SHC NAR	CO CN	07	500 mg/l		SVI	83.	2j 31 3k 4a 5a 5b 5e 5g 5h 51 5t	Oxygen consumption showed no lag period. Material was readily degraded.	52*
							pH	Increased from 6.6 to 6.9 during 24 hr. of aeration.			
							SS	Increased by an average of 126 mg/l from an average initial concentration of 1434 mg/l.			
							BOD	Approximately 96% removal realized in 24 hr. aeration.			
							OU	Stimulated O_2 consumption, chemical fed unit consumed 2.9 to 3.3 times that of the control. Up to 39% of TOD exerted in 24 hr.			
Alcohols	OR	SHC NAR	CO	20			CR	compound removal Hexanol 85% Ethanol 81% Butanol 80% Isopropanol 76% Methanol 46% Ethyl - butanol 44% 2-Ethyl-hexanol 38%	1a,2i 31,4c 5a,5b 5c,5d 5e,5h 5i,5k	Aerated lagoon treatment.	9+

*Refer to Reference No. 49 for additional β-alanine and α-DL-alanine test data

+Refer also to Reference No. 49

1	2	3	4	5	6	7	8	9	10	11	12
Alcohols	OR	SHC NAR	CO	20	500 to 1000 mg/l		CR	Generally, the percentage removal of alcohol from solution was high; 24% to 38% of removal resulted from oxidation, 52% to 66% from conversion to protoplasm.	2j,3k 3l,4a 5a,5b 5e,5g 5h,5l 5t		52*
Aldrin	OR	SHC AR	CX	11			OU CR	<5% of COD exerted Aldrin was not significantly degraded.	4d,5c 5g	Insecticide.	53
Alkyl Benzene Sulfonates**	OR	SHC AR	CO CS	21	100 ppm		OU	n-dodecyl-ABS is not inherently resistant to biological degradation; however, O_2 utilization was lower for keryl-ABS and tetrapropenyl-ABS.	1b,2j 3l,3p 4d,5b 5e,5g 5h,5i	Increased branching on the alkyl group increased resistance to biodegradation.	11
Amines	OR WB	SHC	CN	15			OU	The following aliphatic amines all inhibited oxygen uptake: methyl-ethyl,-n-propyl-, iso-propyl-, n-butyl-, iso-butyl-, sec-butyl, tert-butyl-,n-amyl-,iso-amyl-, n-octyl, and decylamine.	1b,2j 3l,3q 4d,5e 5g,5h 5t	Butylamine was least inhibitory over the 24 hr. period. Sludges did not acclimate to rapid oxidation of amines.	49
Amino Acids	OR AMP	SHC	CO CN	07	500 to 1000 mg/l		CR	22% to 58% of the amino acid was removed by oxidation and 32% to 68% by conversion to protoplasm.	2j,3k 3l,4a 5a,5b 5e,5g 5h,5l 5t		52+

*Refer to Reference No. 49

+Refer to Reference No. 15 and 49 for additional data.

**Unbranched ABS, such as n-dodecyl-ABS, are known as linear alkyl sulfonates or LAS.

1	2	3	4	5	6	7	8	9	10	11	12
Aminotriazole	OR	SHC NAR	CN	11			OU	<5% of measured COD was exerted.	4d,5c 5g	Herbicide.	53
							CR	Chemical was not significantly degraded.			
Ammonia (see also phenol, p. 150)	IN BA	NMC Gas		22	480 mg/l		G	Deleterious effect on activated sludge process Inhibition is greater at higher pH values.	6a		46*
n-Amyl Alcohol	OR	SHC NAR	CO	20					6a	Toxic threshold to sensitive aquatic organisms (approx.) >350 mg/l.	42
sec - Amylbenzene (2-Phenyl-butane)	OR	HC AR		18	500 mg/l		OU	Toxic for 24 hr. of aeration.	1b,2j 3l,4d 5e,5g 5h,5i		45
tert-Amylbenzene	OR	HC AR		18	500 mg/l		OU	Toxic during 24 hr. of aeration.	1b 2j 3l 4d 5e,5g 5h,5i		45

*Refer to Reference No. 32 for additional data.

1	2	3	4	5	6	7	8	9	10	11	12
Aniline	OR WB	SHC AR	CN	20	10 mg/l and 20 mg/l		CD	Increased chemical concentration resulted in increased chlorine demand.	1d,2j 3l,3p 4a,5e 5g	Probable products of chlorination of aniline: 1)o-chloroaniline 2)p-chloroaniline 3)2,4-dichloroaniline 4)2,6-dichloroaniline 5)2,4,6-trichloroaniline 6)non-aromatic oxidation products.	47
Aniline	OR WB	SHC AR	CN	20	500 mg/l		OU	Toxic or inhibitory to O_2 consumption for up to 72 hr.; after 14 hr. up to 30% of TOD was exerted.	1b, 2j 3l,3g 4d,5e 5h,5t	Structurally related bicyclic hydrocarbon, benzidine, was inhibitory.	44
Anthracene	OR	HC AR		19	500 mg/l		OU	Toxic or inhibitory for up to 24 hr., after this period sludge acclimated and chemical was slowly oxidized. In 2 other tests, chemical was readily, but slowly oxidized; up to 12.6% of TOD exerted after 144 hr. of oxidation.	1b 2j 3l 3q 4d 5e 5h 5t	Anthracene, a parent compound of many carcinogens studied, was not as refractory as the carcinogens.	44
Barium (Ba^{++})	IN	CA	HM	05	1 to 100,000 ppm		OU	Greater than 100 ppm caused significant inhibition of oxygen consumption.	2h, 3l 4d,5e 5g,5h		15

1	2	3	4	5	6	7	8	9	10	11	12
Barium (Ba^{++})	IN	CA	HM	05	90 to 300 mg/l				6a	Barium concentration showed varying levels of reduction after chlorination of a municipal water supply.	1
Benzaldehyde	OR	SHC AR	CO	20	4% solution		OU	No O_2 was utilized, thus implying toxicity or resistance to biodegradation.	2h,3l 4d,5e 5g,5h		15
Benzaldehyde	OR	SHC AR	CO	20	500 mg/l		OU	Chemical was readily but very slowly oxidized for first 6 hr. of oxidation. Oxidation increased greatly between 24 and 72 hr. Up to 61.3% of TOD exerted after 144 hrs. of oxidation. Oxygen uptake was not inhibited.	1b,2j 3l,3q 4d,5e 5h,5t	Benzene compounds in order of increasing toxicity or inhibition were benzoic acid, benzaldehyde or benzyl alcohol, then benzonitrile.	44
Benzamide	OR	SHC AR	CO CN	21	500 mg/l		OU	Inhibitory or very slowly oxidized for first 6 hr. Up to 63.3% of TOD exerted after 144 hr. of oxidation.	1b,2j 3l,3q 4d,5e 5h,5t	Rapid oxidation between 24 and 72 hr.	44
1,2-Benzanthracene	OR	AR HC		19	500 mg/l		OU	Not toxic, but very slowly biologically oxidized. Up to 2.1% of TOD exerted in 144 hr. of oxidation.	1b,2j 3l,3q 4d,5e 5h,5t		44

1	2	3	4	5	6	7	8	9	10	11	12
Benzene	OR	AR HC		18		90% to 100%			1a,2i 31,4c 5a,5b 5c,5d 5e,5h 5i,5k	Aerated lagoon treatment.	9
Benzene	OR	AR HC		18		95% to 100%	OT	α value for 10 mg/l of benzene was 1.17; for 35 mg/l, α = 0.97.	1a,2i 31,4c 5b,5d 5e,5g 5h,5i 5k	Completely mixed activated sludge process.	33
Benzene	OR	AR HC		18	500 mg/l		OU	Chemical showed varying toxicity at times from 6 hr. to 144 hr. After 6 hr. up to 0.7% of TOD was exerted; however, after 144 hr. of oxidation up to 53.5% of TOD exerted. In addition, chemical demonstrated various degrees of toxicity to various activated sludges.	1b,2j 31,3q 4d,5e 5h,5t	Chemical forms were both toxic and readily oxidizable. Benzene compounds in order of decreasing toxicity were nitrobenzene, benzylamine, benzenethiol (all toxic); benzonitirle, or benzene, or benzyl alcohol; benzaldehyde; and benzoic acid.	44

1	2	3	4	5	6	7	8	9	10	11	12
Benzene	OR	AR HC		18	125 mg/l		OU	1.44 to 1.45 g of 0 utilized per gram of substrate added after 72 hr. of oxidation.	1b,2j 3l,4b 4d,5b 5c,5e 5g,5h 5i,5k	Although the 2 chemical concentrations of 50 mg/l and 500 mg/l showed similar effects, BOD removal was 3 to 4%<control unit and oxygen consumption rates indicated some inhibition when compared with the control.	29
					50 mg/l and 500 mg/l		OU	Rate of 34 mgO$_2$/l/hr. for 50 mg/l chemical and 37 mg/l/hr. for 500 mg/l chemical.			
							BOD	Removal efficiency was practically the same for both chemical concentrations.			
1,4-Benzenediol (Hydroquinone)	OR	SHC AR	CO	12	10 mg/l and 25 mg/l		CD	Increased chemical concentration resulted in increased chlorine demand Increased chlorine application resulted in decreased chlorine demand.	1d 2j 3l 3p 4a 5e 5g	Probable products of chlorination of hydroquinone: 1)p-benzoquinone 2)non-aromatic oxidation products.	47
Benzene Sulfonate (Sodium salt)	OR	SHC AR AN	CS	21	500 mg/l		OU	Readily, but slowly, oxidized for first 6 hr. oxidation increased rapidly thereafter. Up to 62% of TOD exerted after 144 hr.	1b,5e 2j,5h 3l,5t 3g 4d		44

1	2	3	4	5	6	7	8	9	10	11	12
Benzenethiol	OR	SHC AR	CS	12	500 mg/l		OU	Toxicity reflected by inhibition of oxygen uptake for up to 144 hr. of oxidation.	1b,2j 3l,3q 4d,5e 5h,5t		44
Benzidine	OR WB	SHC AR	CN	15	500 mg/l		OU	Toxicity reflected by inhibited oxygen uptake for up to 144 hr. of oxidation.	1b,2j 3l,3q 4d,5e 5h,5t	Carcinogenic compound.	44
Benzonitrile	OR	SHC AR	CN	15	500 mg/l		OU	Inhibitory for up to 72 hr. of oxidation.	1b,2j 3l,3p 3q,4d 5e,5g 5h,5i 5t	Aromatic nitrile.	43
Benzonitrile	OR	SHC AR	CN	15	500 mg/l		OU	Toxicity or inhibition up to 72 hr. of oxidation reflected by the inhibition of oxygen uptake. After 144 hr. up to 43% of TOD exerted.	1b,2j 3l,3q 4d,5e 5h,5t	A requirement for sludge acclimation was indicated for chemical.	44
3,4-Benzpyrene (contd.)	OR	HC AR		19	500 mg/l		OU	Readily, but slowly, oxidized. Up to 6.1% of TOD exerted after 144 hr. of oxidation.	1b,2j 3l,3q 4d,5e 5h,5t	Doubling MLSS (mixed liquor suspended solids) to 5000 mg/l increased the % of TOD exerted after 144 hr. of oxidation,	44

1	2	3	4	5	6	7	8	9	10	11	12
3,4-Benzpyrene (contd.)										but did not improve oxidation after 6 hr. or 24 hr.	
Benzylamine	OR WB	SHC AR	CN	15	500 mg/l		OU	Toxicity reflected by inhibition of oxygen uptake at all times up to 144 hr. of oxidation.	1b,2j 3l,3q 4d,5e 5h,5t		44
4,4'-Bis (dimethylamino)benzophenone	OR	SHC AR	CO CN	21	500 mg/l		OU	2 of 3 sludges showed lag periods for up to 72 hr. before biological oxidation of chemical began. One sludge readily but slowly oxidized chemical.	1b,2j 3l,3q 4d,5e 5h,5t	Up to 4.5% of TOD exerted after 144 hr. of oxidation.	44
Boron (Borates, B_xO_x)	IN	MC		04	1 to 100,000 ppm		OU	About 10 ppm caused significant inhibition.	2h,3l 4d,5e 5g,5h	In general, anions were less toxic than cations.	15
Boron (Borate, BO_3^-)	IN	NMC SA		04	0.05 mg/l		G	Detrimentally affected activated sludge process.	6a		46
							SSR	Greatly reduced.			
(contd.)											

1	2	3	4	5	6	7	8	9	10	11	12
Boron (contd.)	IN	NMC SA		04	10 mg/l		G	>10 mg/l produced significant inhibition in activated sludge cultures.	1d 2k 3l 4d 5a 5e 5g 5h 5i 6a	Current Boron levels in sewage 0.4-1.5 mg/l.	3
							SMC	At pH 7.0, activated sludge would adsorb 25mg of Boron/g of sludge in 1 mg/l boron solution at 31°C. Increased boron concentration resulted in increased adsorption. Lower temperatures may result in increased adsorption.			
					1 to 100 mg/l		OU	>10 mg/l B caused reduction of the endogenous respiration of sludge and may have significant affect on extended aeration or aerobic sludge digestion.			

1	2	3	4	5	6	7	8	9	10	11	12
Boron (Borate, BO_3^-)	IN	NMC AN		04	50 mg/1		COD	COD removal rate was lower than control.	1d 2h 3l 3p 4a 5a 5c 5e 5f 5h 5i 5l 6a	Boric acid and sodium borate were utilized as sources of boron.	4
					0-400 mg/1		COD	Increased B conc. caused COD removal rate (i.e., mg/hr/g of MLSS) to decrease almost exponentially.			
							SP	The fraction of COD synthesized to sludge was not affected by the B conc. but was about constant in proportion to the substrate removed.			
							SSR	At>100 mg/1 of B the settling characteristics of the sludge were adversely affected.			
Boron (Borate, BO_3^-)	IN	NMC SA		04	0.005 to 0.05 mg/1		MI	No stimulation or inhibition of growth.	1d,2k 3k,4a 5a	Growth of Nitrosomonas studied.	39

1	2	3	4	5	6	7	8	9	10	11	12
Brewery Waste					average COD - 650 mg/l		SSR	Settleability reduced at both extremes of organic loading.	1a 2g 3l 4a 5b 5c 5g 5k 7a	Waste was not toxic to bacterial degradation. However, oxygen consumption seemed to plateau, while in the unit fed domestic sewage oxygen consumption continued to increase. Dehydrogenase measurement proved to be valid as a true sludge-activity parameter.	71
							OU	Increased organic loading resulted in increased O_2 uptake.			
							COD	Removal efficiency decreased as organic loading increased.			
							SVI	Increased rapidly at loadings > 0.6 lb. BOD_5/day/lb solids.			
							DE	Closely related to O_2 uptake; increased as organic loading increased.			
Butanamide (Butyramide)	OR	SHC NAR	CO CN	21	500 mg/l		OU	Readily, but slowly, oxidized with 6.4% of TOD exerted after 24 hr. of oxidation. Oxygen uptake increased during entire 24 hr. study.	1b,2j 3l,3q 4d,5e 5g,5h 5t		49

1	2	3	4	5	6	7	8	9	10	11	12
Butanedinitrile (Succinonitrile)	OR	SHC NAR	CN	15	500 mg/1		OU	Toxic at oxidation periods up to 72 hr.	1b,2j 31,3p 3q,4d 5e,5g 5h,5i 5t	Dinitrile compound was toxic whereas corresponding nitrile had up to 10.8% of TOD exerted after 72 hr. of oxidation. Corresponding monocarboxylic acid (butanoic or butyric acid) had up to 43.0% of TOD exerted in 72 hr. of oxidation.	43
Butanedinitrile (Succinonitrile)	OR	SHC NAR	CN	15	500 mg/1		OU	Readily, but slowly oxidized, 3.8% of TOD exerted after 24 hr. of oxidation. Oxygen uptake showed plateau effect after 12 hr.	1b,2j 31,3q 4d,5e 5g,5h 5t	Butanedinitrile showed greater oxidation than butanenitrile.	49

1	2	3	4	5	6	7	8	9	10	11	12
Butanenitrile (Butyronitrile)	OR	SHC NAR	CN	15	500 mg/l		OU	Inhibited oxidation for up to 24 hr.; after 72 hr., up to 10.5% of TOD was exerted.	1b,2j 3l,3p 3q,4d 5e,5g 5h,5i 5t	Refractory nature decreases with increasing chain length. Corresponding dinitrile was more inhibitory with up to 10.8% of TOD exerted after 72 hr. oxidation. Corresponding monocarboxylic acid (butanoic or butyric acid) had up to 43.0% of TOD exerted in 72 hr. of oxidation.	43
Butanenitrile (Butyronitrile)	OR	SHC NAR	CN	15	500 mg/l		OU	Readily, but slowly oxidized. Most rapid oxidation occurred in first 6 hr., 1.7% of TOD exerted after 24 hr. Oxygen uptake showed plateau after 12 hr.	1b,2j 3h,3q 4d,5e 5g,5h 5t		49
Butanol	OR	SHC NAR	CO	20		70% to 90%			1a,2i 3l,4c 5a,5b 5c,5d 5e,5h 5i,5k	Aerated lagoon treatment.	9

1	2	3	4	5	6	7	8	9	10	11	12
Butanol	OR	SHC NAR	CO	20		95% to 100%			1a,2i 3l,4c 5b,5d 5e,5g 5h,5i 5k	Completely mixed activated sludge process; at 80% BOD removal, achieved 98% chemical removal.	33
Butanol	OR	SHC NAR	CO	20					6a	Toxic threshold to sensitive aquatic organisms (approx.) <250 mg/l.	42
tert-Butanol	OR	SHC NAR	CO	20					1d,2j 3l,3p 4a,5e 5g	Substrate partially degraded (very slowly). Degradation product formation was unknown.	47
Butyl-benzenes: n-Butyl- tert-Butyl-	OR	HC AR		18	100 ppm		OU	n-Butylbenzene was more susceptible to degradation than tert-Butylbenzene.	1b,2j 3l,3p 4d,5b 5e,5g 5h,5i	Neither of the chemicals were very susceptible to degradation; however, branching increased the refractory nature of the chemicals.	11

1	2	3	4	5	6	7	8	9	10	11	12
sec-Butylbenzene (2-Phenyl-butane)	OR	HC AR		18	500 mg/l		OU	Toxic for 24 hr. of aeration.	1b,2j 3l,4d 5e,5g 5h,5i		45
tert-Butyl-benzene	OR	HC AR		18	500 mg/l		OU	Toxic or inhibitory during 24 hr. of aeration.	1b,2j 3l,4d 5e,5g 5h,5i		45
n-Butyl ester of 2,4,5-T (See also: pp. 169-70)	OR	SHC AR	CO CX	11			OU	20% of measured COD was exerted.	4d,5c 5g	Herbicide.	53
							CR	Chemical was materially degraded.			
2,3-Butylene Oxide	OR	SHC NAR	CO	20	500 mg/l		OU	Up to 9.6% of TOD exerted after 144 hr. of oxidation when utilizing a sludge of 2500 mg/l MLSS. Doubling MLSS did not appreciably increase the degree of chemical oxidation.	1b 2j,3l 3q,4d 5e,5h 5t	Degraded very slowly.	44
Butyric Acid	OR WA	SHC NAR	CO	07	500 mg/l		OU	Up to 43% of TOD exerted after 72 hr. of oxidation.	1b,2j 3l,3p 3q,4d 5e,5g 5h,5i 5t	Corresponding mono- and di-nitriles having same number of carbon atoms were much more slowly oxidized.	43

1	2	3	4	5	6	7	8	9	10	11	12
Butyric Acid	OR WA	SHC NAR	CO	07		50% to 70%			1a,2i 31,4c 5a,5b 5c,5d 5e,5h 5i,5k	Aerated lagoon treatment.	9
Butyric Acid	OR WA	SHC NAR	CO	07	500 mg/1		OU	Chemical was oxidized rapidly for first 6 hr.; after 24 hr. of oxidation up to 27.9% of TOD was exerted.	1b,2j 31,3q 4d,5e 5g,5h 5t		49
Cadmium (Cd^{+2})	IN	CA	HM	05			SO	Inhibits.			8
Cadmium (Cd^{+2})	IN	CA	HM	05	1 to 10,000ppm		OU	Greater than 1 ppm cadmium and less than 10 ppm significantly inhibited O_2 uptake.	2h,31 4d,5e 5g,5h		15
Cadmium (Cd^{+2})	IN	CA	HM	05			pH	Inhibitory effects start to decrease rapidly as pH approaches 7.4 .			51
Cadmium and Manganese Mixture	IN IN	CA CA	HM HM	05	10 ppm cadmium, 100 ppm manganese		OU	Mixture of Cd and Mn was more inhibitory than a similar concentration of either individually.	2h,31 4d,5e 5g,5h		15

1	2	3	4	5	6	7	8	9	10	11	12
Cadmium and Zinc Mixture	IN IN	CA CA	HM HM	05	10 ppm cadmium, 10 ppm zinc		OU	Mixture of Cd and Zn was more inhibitory than a similar concentration of either element individually.	2h,31 4d,5e 5g,5h		15
Calcium Gluconate	OR ST	SHC NAR	CO	04	250 mg/1		SVI	64.6.	2j 3k 31 4a 5a 5b 5e 5g 5h 51 5t	There was an initial lag period of 3 hr after which material inhibited O_2 uptake but was susceptible to biodegradation.	52
							pH	Decreased from 7.4 to 6.5 during 24 hr. of aeration.			
							SS	Concentration did not change significantly.			
							BOD	62% to 73% removal after 24 hr. of aeration.			
							OU	29 mg of O_2 utilized in 24 hr. This was 78% less than control. 13.6% of TOD exerted in 24 hr.			
Captan®	OR	SHC AR	CO CN CS CX	11			OU	Inhibited, oxygen utilization was at least 10% below control at 300 minutes.	4d 5c 5g	Fungicide.	53
							CR	Chemical was not degraded.			

1	2	3	4	5	6	7	8	9	10	11	12
Carbohydrates	OR	SHC NAR	CO	21	500 to 1000 mg/l		CR	5% to 24% of the carbohydrate was removed by oxidation and 65% to 85% by conversion to protoplasm.	2j,3k 3l,4a 5a,5b 5e,5g 5h,5l 5t		52
Carboxylic Acids (Short chain)	OR WA	SHC NAR	CO	07	500 mg/l				1b 2j 3l 3q 4d 5e 5g 5h 5i	Di-carboxylic acids were less susceptible to biological oxidation then corresponding monocarboxylic acids. Cyanide replacing carboxyl grouping of saturated acid greatly reduced oxidizability. Sludges did not acclimate to dicarboxylic acids in 24 hr.	49
Chlorate (ClO_3^-)	IN	NMC AN		04	1 to 100,000 ppm		OU	10 ppm of chlorate and greater, significantly inhibited.	2h,3l 4d,5e 5g,5h		15

1	2	3	4	5	6	7	8	9	10	11	12
Chloranil	OR	SHC AR	CO CX	11	10 mg/1		OU	Inhibitory.	1d,2j 31,4d 5e,5g	Higher concentration not studied because of insolubility.	47
Chlordane	OR	SHC AR	CX	11			OU	5-20% of COD exerted.	4d 5c 5g	Insecticide.	53
							CR	Chemical was only slightly degraded.			
Chlorine	IN	Gas		22	175 mg/1 and 525 mg/1		SF	Increasing the chlorine dosage to undigested activated sludge decreased filtration time 100% and 400%, respectively.	1b,2g 31,3m 4a,4b 5a,5b 5c,5e 5g,5h 5i,5s 5z	Chlorination was found to be detrimental to sludge filterability. Aeration did not improve filterability of chlorinated sludges.	69
4-Chloro-3-methylphenol (4-Chloro-m-cresol)	OR WA	SHC AR	CO CX	12	10 mg/1		OU	Mildly inhibitory.	1d,2j 31,4d 5e,5g		47
					50 mg/1		OU	Strongly inhibitory.			
					100 mg/1		OU	Toxic.			

1	2	3	4	5	6	7	8	9	10	11	12
Chromium, total	IN	SA	HM	05	0.8 mg/l	75%			1c,2i 3l,4c 5a,5b 5c,5h 5j,5k	Bryan, Ohio - overall removal.	5
					3.6 mg/l	31%				Grand Rapids, Mich. - overall removal.	
					0.8 mg/l	75%				Richmond, Ind.- overall removal .	
					0.9 mg/l	78%				Bryan, Ohio - secondary removal .	
					3.2 mg/l	22%				Grand Rapids, Mich. - secondary removal .	
					0.8 mg/l	75%				Richmond, Ind.- secondary removal.	
Chromium	IN	SA	HM	05	56 to 152 mg/l	91 to 99%	BOD	Removal not affected.	1a,2g 3l,4b 5a,5b 5h,5k	While overall removal was high, activated sludge removed less than 20% of chromium from tannery waste.	28
							SS	Removal not affected.			

1	2	3	4	5	6	7	8	9	10	11	12
Chromium	IN	SA	HM	05	3.6 mg/l		SMC	40% of metal immobilized in sludge.	1c 4c	Grand Rapids, Michigan.	58
					0.8 mg/l		SMC	82% of metal immobilized in sludge.		Richmond, Ind.	
Chromium (Chromic, Cr^{+3}, also referred to as trivalent chromium or reduced chromium)	IN	CA	HM	05	0.5 to 50 mg/l		SAND	Gas production not affected. Continuous feed showed a cumulative inhibitory effect.	1b,2g 3m,3p 4b,5b 5c,5h 5i,5k	Nearly all chromium in sludge fed to digestor was in reduced, insoluble form.	12
					100 mg/l		SAND	Gas production stopped for 7 days, system recovered in 25 days.			
					500 mg/l		SAND	Digestor completely upset.			
Chromium (Chromate, CrO_4^{-2}, also referred to as hexavalent chromium, Cr^{+6})	IN	AN	HM	05	0.5 to 50 mg/l		BOD	At 50 mg/l chromium, BOD removal was 3% less than control.	1b 2g 3l 3p 4b 5b 5c 5h 5i 5k	Chemical fed as potassium chromate. Hexavalent chromium was reduced to trivalent chromium which has little toxicity to activated sludge. However, as the influent Cr^{+6} conc.	12
							COD	At 50 mg/l chemical concentration, COD removal was 4% less than control.			
							SS	Removal not affected by chemical concentrations.			
(contd.)							SMC	Sludge adsorbed and reduced a portion of the soluble chromium. Chromium build-up in			

1	2	3	4	5	6	7	8	9	10	11	12
Chromium, (Chromate, see previous page) (contd.)								sludge increased with increasing chemical concentrations. Mixed liquor solids contained 10 times more Cr than primary solids.		increased, a larger proportion of the primary effluent Cr was soluble. Nitrification was inhibited for short periods, but bacteria acclimated to up to 50 mg/l Cr^{+6} added continuously.	
Chromium	IN	SA	HM	05	10 mg/l		G	Slug dose over 4 hr. period had no effect on performance.	1b 2h 31 3p 4b 5b 5c 5h 5i 5k	All concentrations inhibited nitrification for approximately 10 days.	12
					100 mg/l		BOD COD SS	Slug dose over 4 hr. period resulted in 3% decrease in BOD removal during first 24 hr. COD removal decreased 14%,SS removal showed same effect. System recovered in 2 days.			
(contd.)											

1	2	3	4	5	6	7	8	9	10	11	12
Chromium (contd.)					500 mg/l		BOD COD SS T	Slug dose over 4 hr. showed immediate effect on system. BOD and COD removal dropped for 32 hr. Effluent SS increased. System recovered in 4 days.			
Chromium	IN	SA	HM	05	7 mg/l		BOD	Removal efficiency decreased from 95% to 70%.	6a		46
							T	Effluent turbidity increased.			
					10 mg/l		G	Lowest continuous dose that causes an effect.			
					500 mg/l or greater		G	Lowest 4 hr. duration slug dose which would produce a 24 hr. effect on the effluent.			
							SSR SVI	Chromate likely to cause bulking sludge because it has a lesser effect on filamentous organisms.			
					50 mg/l chromate		BOD	Showed little effect on removal efficiency.			
(contd.)					100 mg/l chromate		BOD	Slug dose caused 3% decrease in BOD removal efficiency. Plant recovered in 20 hr.			

1	2	3	4	5	6	7	8	9	10	11	12
Chromium (contd.)					500 mg/l		BOD	Removal efficiency decreased for 32 hr., returned to normal in 4 days.			
							T	Increased for 24 hr.			
							N	Inhibited for 10 days.			
Chromium (Chromate ion, p.59)	IN	AN	HM	05	15 mg/l		SMC	2.4% of added metal found in raw sludge; 27% found in activated sludge.	6a		46
Chromium (Chromic ion, Cr^{+3}, see p. 59)	IN	CA	HM	05	0 to 50 mg/l of Cr^{+3}		G	Up to 50 mg/l of Cr^{+3} produced no significant reduction in efficiency of biological filters.	1b 2g 31 4b 5b 5h 5k 5n 51 6a		2
							N	15 mg/l Cr^{+3} caused noticeable reduction of nitrification but BOD and solids removal were unaffected and effluent chrome content remained low. Nitrification recovered somewhat after 2 weeks at this Cr^{+3} level.			
(contd.)							SVI	reduced from 85 to 65 when 15 mg/l Cr^{+3} in feed.			

1	2	3	4	5	6	7	8	9	10	11	12
Chromium (contd.)							CR	Effluent conc. of 0.2 mg/l occurred when 15 mg/l Cr^{+3} fed. Cr^{+3} removed in sludge.			
Chromium (Chromate, see p.59)	IN	AN	HM	05	10 mg/l		G	Threshold limit before significant reduction in aerobic treatment efficiency.	1b 2g 31 4b		6
					>500 mg/l		G	Will cause adverse effect.	1b 2a 31 4b	Slug dose over 4 hr.	
					15 mg/l	44%	SMC	2.4% of metal fed found in primary sludge; 27% of metal fed found in excess activated sludge; 56% of metal fed found in final effluent.	1b 2g 31 4b	Activated sludge showed poor removal of chromium.	
Chromium (Chromate, see p. 59)	IN	AN	HM	05	All Conc.		SO	Inhibits.			8
							SMC	Partially precipitated or adsorbed by sludge.			
					1-4 ppm		G	tolerable concentration.	2g		
					5-10 ppm		G	causes significant effect.	2g		
					10-50 ppm		G	causes temporary impairment.	2h		
					100-500ppm		G	causes considerable impairment.	2h		

1	2	3	4	5	6	7	8	9	10	11	12
Chromium (Chromate, see p. 59)	IN	AN	HM	05	2 mg/l		N	Inhibited.	6a		46
					5 mg/l		N	3 to 4 doses completely arrested it.			
							SO	Concentrations greater than 5 mg/l inhibited oxidation and flocculation.			
					430 mg/l and 1440 mg/l		DO	Increased and remained high for 14 days.		Slug dose on two consecutive days at pH 4.2 and 4.0.	
							N	Returned to normal in 10 days.			
							T	Effluent turbid for several days, cleared in 10 days.			
					10 mg/l to 15 mg/l		G	Aerobic process affected slightly; recovery is quick.			
Chromium (Chromate, see p. 59)	IN	AN	HM	05	1 to 100,000ppm		OU	100 ppm and greater significantly inhibited.	2h,31 4d,5e 5g,5h		15
Chromium (chromate) and Copper Mixture	IN IN	AN CA	HM HM	05 05	100 ppm chromate. 10 ppm copper		OU	Mixture depressed O_2 uptake slightly more than did copper alone, but significantly more than did chromate alone.	2h,31 4d,5e 5g,5h		15

1	2	3	4	5	6	7	8	9	10	11	12
Chromium (chromate) and Iron Mixture	IN	AN	HM	05	100 ppm chromate,		OU	Mixture depressed O_2 uptake more than either chemical individually.	2h,3l 4d,5e 5g,5h		15
	IN	CA	HM	05	100 ppm iron						
Citric Acid	OR WA	SHO NAR	CO	07	550 mg/l		SVI	62.2	2j 3k 3l 4a 5a 5b 5e 5g 5h 5l 5t	Oxidation started slowly with little oxygen utilization until fifth through twenty-fourth hour when citric acid was sole source of carbon or energy.	52
							pH	increased from 7.3 to 7.4 during 24 hr. of aeration.			
							SS	increased 36 mg/l and 84 mg/l during 24 hr.			
							BOD	in excess of 98% removal in 24 hr.			
							OU	35 mg of O_2 used in 24 hr This was 22% oxygen consumption of the control. Up to 15% of TOD exerted in 24 hr.			
					720 mg/l		OU	Results were irregular; there was zero oxidation and 30% oxidation on two tests.			
Cobalt (Ionic)	IN	CA	HM	05	0.005 to 0.5 mg/l		MI	No conc. tested showed stimulation; 0.08 to 0.5 mg/l inhibited growth.	1d,2k 3k,4a 5a	Growth of *Nitrosomonas* studied.	39

1	2	3	4	5	6	7	8	9	10	11	12
Coke Plant Weak Ammonia Liquor					phenols- 50 to 300 mg/l; cyanide- 5 to 70 mg/l; emulsified oils		NB	Phosphorus must be added at P to phenol ratio of 1.70.	1a 2g 3l 3p 4c 4d 5a 5f	Phenol removals >99.8% were realized at phenol loadings of 30 lb/day/ 100 ft^3 at sludge conc. of 5700 ppm in 1.6 hr. detention time. Lowering ammonium ion conc. to 2000 mg/l improved phenol removal. Dissolved tars prohibited phenol oxidation. Optimum temperature was found to be 95° F. Foaming problems did occur. Anti-foam agents dosed at 1 ppm solved foam problem and did not affect O_2 transfer. Thiocyanate removal averaged 70%. Cyanide was present as complexes and thus	32
							pH	Influent pH was 8.3 to 8.8 while effluent pH was 6.0 to 7.9.			
							N	No nitrification occurred.			

(contd.)

1	2	3	4	5	6	7	8	9	10	11	12
Coke Plant Weak Ammonia Liquor (contd.)										had little toxic effect.	
Copper (Cupric, Cu^{+2})	IN	CA	HM	05	30 mg/l		COD	A slug dose of Cu for 6 hr. caused effluent COD to rise in proportion to the Cu^{+2} added on a 1:1 basis (i.e., 1 mg/l increase in COD for 1 mg/l of Cu in slug dose). Maximum effluent COD increase occurred 9 to 13 hr. after slug. System returned to normal after 24 hr.	1d 2h 31 4b 5a 5c 5e 5h 5k 6a	Increasing the solids conc. minimized the effect of a slug of Cu (with regard to effluent COD).	17*
					15 to 45 mg/l		SS	Toxic effects of Cu^{+2} are less at higher solids concentrations; increased solids concentrations were more advantageous at lower organic loadings.			
Copper (Cu^{+2})	IN	CA	HM	05	1 mg/l		G	Lowest continuous dose that causes an effect.	6a	Cyanide complexes of Cu produce reactions similar to those of the Cu sulfate salts. The dumping of a copper cyanide bath	46
					75 mg/l		G	Lowest 4 hr. duration slug dose which would produce a 24 hr. effect on the effluent.			
(contd.)					3.6 mg/l		BOD	Removal efficiency dropped 24%.			

* Refer to References 8, 57, and 58 for additional data.

1	2	3	4	5	6	7	8	9	10	11	12
Copper (contd.)							SVI	Increased until activated sludge process failed completely.		resulted in a cyanide conc. of 8.6 mg/l and copper conc. of 3.6 mg/l. Deterioration of activated sludge was noted 36 hr. after dumping.	
							SSR	Light, fluffy, non-setteable sludge was obtained even a week after the spill.			
					10 mg/l	75%	SMC	55% of added metal was found in activated sludge.			
Copper (Cu^{+2})	IN	CA	HM	05	0.2 mg/l	50%			1c,2i 31,4c 5a,5b 5c,5h 5j,5k	Bryan, Ohio - overall removal of Cu.	5
					1.4 mg/l	15% increase				Grand Rapids, Mich.- overall removal of Cu.	
					0.2 mg/l	65%				Richmond, Ind.- overall removal of Cu.	
					0.2 mg/l	22%				Bryan, Ohio - secondary removal of Cu.	
					1.5 mg/l	7% increase				Grand Rapids, Mich.- secondary removal of Cu.	
					0.3 mg/l	77%				Richmond, Ind.- secondary removal of Cu.	

1	2	3	4	5	6	7	8	9	10	11	12
Copper (Cu^{+2})	IN	CA	HM	05	0.005 to 0.56 mg/l		MI	Conc. at which the following effects were observed: Stimulation-0.005 to 0.03 mg/l Inhibition -0.05 to 0.56 mg/l	1d 2k 3k 4a 5a	Growth of Nitrosomonas studied	39
Copper (Cu^{+2})	IN	CA	HM	05	1.0 mg/l and 5.0 mg/l		COD	The effect of 5 mg/l Copper and the higher organic loading were roughly additive. No differences were detect for 1 mg/l Copper at either organic loading (24 lb and 57 lb COD/day/1000 ft^3 aeration capacity.	1b,2h 3l,3p 4b,5b 5c,5h 5i,5k	At higher organic loading a greater percent of effluent Cu was in a soluble form. Moderate variation in organic loading did not alter the effect of Cu significantly	12*
Copper (Cu^{+2})	IN	CA	HM	05	30 to 40 mg/l				6a	Copper conc. increased significantly after chlorination of a municipal water supply.	1*
Copper	IN	CA	HM	05	10 mg/l		SMC	9% of metal added was found in raw sludge.	6a		46*
(contd.)					8.8 mg/l		SMC	Metal in raw sludge was			

*Refer to Reference No. 12 for data collected under continuous loading conditions.

1	2	3	4	5	6	7	8	9	10	11	12
Copper (contd.)								18 times greater in sewage.			
Copper (Cu^{+2})	IN	CA	HM	05	1 mg/l		G	Threshold limit before significant reduction in aerobic treatment efficiency.	1b 2g 31 4b		6*
					75 mg/l		G	Will cause harmful effect.	1b,2h 31,4b	Slug dose over 4 hr.	
					10 mg/l	75%	SMC	9% of metal fed found in primary sludge; 55% of metal fed found in excess activated sludge; 25% of metal fed found in final effluent.	1b 2g 31 ;4b	A large proportion of the copper was found tied up in the activated sludge.	
Copper and Chromate Mixture	IN	CA	HM	05	10 ppm copper, 100 ppm chromate		OU	The Cu-chromate mixture was slightly more toxic or inhibitory than Cu alone and significantly more toxic than was chromate alone.	2h,31 4d,5e 5g,5h		15
	IN	MC AN		05							
Copper and Cyanide Mixture	IN	CA	HM	13	10 ppm copper, 100 ppm cyanide		OU	Mixture depressed O_2 uptake more than did Copper alone, but less than cyanide alone.	2h,31 4d,5e 5g,5h		15*
	IN	NMC AN		13							

*Refer to Reference No. 12 for data collected under continuous loading conditions.

1	2	3	4	5	6	7	8	9	10	11	12
Copper and Iron Mixture	IN IN	CA CA	HM HM	05 05	10 ppm copper, 100 ppm iron		OU	The Cu-Fe mixture was more toxic or inhibitory than iron was alone, but less toxic than was copper alone.	2h,31 4d,5e 5g,5h		15
Copper and Nickel Mixture	IN IN	CA CA	HM HM	05 05	10 ppm copper, 10 ppm nickel		OU	The Cu-Ni mixture depressed O_2 uptake more than did either element individually.	2h,31 4d,5e 5g,5h		15
Copper, elemental and compounds	IN IN	EL SA		01 05	10,000mg/1 copper		OU	Copper compounds in order of decreasing toxicity or inhibition were: copper metallic, copper oxide.			15
					100 mg/1 copper		OU	Copper compounds in order of decreasing toxicity or inhibition were: copper chloride, copper sulfate.			
					10 mg/1 copper			Copper compounds in order of decreasing toxicity or inhibition were: copper sulfate, copper chloride.			

1	2	3	4	5	6	7	8	9	10	11	12
Cotton Kier Liquor							TP	Adaptation of activated sludge to temperature change was immediate. Fluctuations between 10° and 30°C at 12 hr. intervals were not detrimental to sludge quality.	1a 2g 3l 4a 5a 5b 5e 5i 5k 5s 7a	Alkaline waste with a BOD of 800 mg/l was successfully treated.	72
							pH	Effects are a function of temperature. pH>9 was inhibitory at 10°C; pH>10 inhibitory at 30°C.			
							G	Sludge could be starved at least 3 weeks without seriously impairing purification capacity. Full capacity restored 2 to 5 days after resumption of full load. Removal was more efficient at 30° C than 10°C and at neutral pH.			
							BOD	Removal was more efficient at 30°C than 10°C and at neutral pH.			

1	2	3	4	5	6	7	8	9	10	11	12
m-Cresol (contd.)	OR WA	SHC AR	CO	12	10 mg/l and 20 mg/l		CD	Increasing m-cresol conc. resulted in decreasing chlorine demand.	1d 2j 3l 3p 4a 5e 5g	Probable products of chlorination of m-Cresol: 1) 2-chloro-3-methyl-phenol 2) 4-chloro-3-methyl-phenol 3) 6-chloro-3-methyl-phenol 4) 2,4-dichloro-3-methyl-phenol 5) 2,6-dichloro-3-methyl-phenol 6) 4,6-dichloro-3-methyl-phenol 7) 2,4,6-trichloro-3-methyl-phenol 8) Non-aromatic oxidation products	47

1	2	3	4	5	6	7	8	9	10	11	12
m-Cresol (contd.)										Chemical undergoes biological oxidation.	
Croton-aldehyde	OR	SHC NAR	CO	20		90% to 100%			1a,2i 31,4c 5a,5b 5c,5d 5e,5h 5i,5k	Aerated lagoon treatment.	9
Croton-aldehyde	OR	SHC NAR	CO	20		95% to 100%			1a,2i 31,4c 5b,5d 5e,5g 5h,5i 5k	Completely mixed activated sludge process.	33
Cyanide (CN^-, in complexes with various metals)	IN	AN	CN	13	2 to 3 mg/1		N G	Retarded. Little tendency of activated sludge to acclimate to chemical; however, recovery from slug load of 40 mg/1 occurred in about two days.	1c 2g 2h 31 4a 5b 6a	Metallocyanide complexes vary greatly in stability; cadmium and zinc dissociate readily under normal sewage conditions while the copper complex is more stable	24*
(contd.)					200 mg/1		CR	Trickling filters provided with proper acclimation could realize 99% cyanide removal; however, BOD			

*Refer to Reference No. 15 and 40 for respirometer and bottle test data.

1	2	3	4	5	6	7	8	9	10	11	12
Cyanide (contd.)								reduction was less efficient.		and the iron complex extremely stable, with the nickel complex slightly less stable.	
Cyanide	IN	CA	CN	13			CR	>30ppm chromate and >10ppm copper caused no effect on cyanide removal. A few ppm Ni accelerated oxidation of cyanide. The presence of heavy metals in waste required excess aeration for mixing to prevent sedimentation of sludge.			50
Cyanide and Copper Mixture	IN	AN	CN	13	100ppm cyanide, 10ppm copper		OU	Mixture of cyanide and Cu was more toxic and inhibitory than was copper alone, but less than was cyanide alone.	2h,31 4d,5e 5g,5h	Refer to "Cyanide" on p. 74.	15
	IN	CA	HM	05							

1	2	3	4	5	6	7	8	9	10	11	12
Cyanide and Nickel Mixture	IN CA	TA		13	100 ppm cyanide, 10 ppm nickel		OU	Mixture of cyanide and Ni was more toxic or inhibitory than was nickel alone, but less than was cyanide alone.	2h,3l 4d,5e 5g,5h	See cyanide entry on p. 74.	15
	IN	EL	HM	13							
Cystine	OR AMP	SHC NAR	CO CN CS	08	1000 mg/l		SVI	50.8.	2j 3l 3k 4a 5a 5b 5e 5g 5h 5l 5t	Since cystine was sole source of carbon or energy, it may have been toxic, not biodegradable, or degradable after a lag period longer than the duration of the study.	52*
							pH	Decreased from 6.6 to 5.7 during 24 hr. of aeration.			
							SS	Decreased by an average of 201 mg/l from an average initial conc. of 2854 mg/l.			
							OU	Completely inhibited any consumption of O_2. None of TOD was exerted in 24 hr. of aeration.			
L-Cystine (Dicysteine)	OR AMP	SHC NAR	CO CN CS	08	500 mg/l		OU	Readily, but slowly oxidized, with 4.7% of TOD exerted after 24 hr. of oxidation. O_2 uptake increased during entire 24 hr. of oxidation; however, oxygen consumption was significantly less than that for almost all other amino acids studied.	1b 2j 3l 3q 4d 5e 5g 5h 5t	Chemical was more refractory than most of the other amino acids studied.	49

*Refer to Reference No. 49 for respirometer data.

1	2	3	4	5	6	7	8	9	10	11	12
DDT (1,1,1-Trichloro-2,2-bis (p-chloro-phenyl) - ethane	OR	SHC AR	CX	11			OU	<5% of measured COD was utilized.	4d 5c 5g	Insecticide.	53
							CR	Chemical was not significantly degraded.			
Defoamer (Nalco 71-05®)							OT	α value for 2 mg/l of defoamer is 0.80; for 6 mg/l, α = 0.65.	1a,2i 3l,4c 5b,5d 5e,5g 5h,5i 5k	Completely mixed activated sludge process.	33
Diazinon®	OR	SHC AR	CO CP CS CN	11			OU	<5% of measured COD was utilized.	4d 5c 5g	Insecticide.	53
							CR	Chemical was not significantly degraded.			
Dibenz (a,h) acridine	OR	SHC AR	CN	15	500 mg/l		OU	In two cases, chemical was slowly but readily degraded. In a third case it was toxic or insignificantly degraded. Up to 4.6% of TOD exerted after 144 hr. of oxidation.	1b 2j 3l 3q 4d 5e 5h 5t	Doubling MLSS to 5000 mg/l greatly improved biological oxidation after 6,24, and 144 hr. Up to 17.3% of TOD exerted after 144 hr. of oxidation.	44

1	2	3	4	5	6	7	8	9	10	11	12
Dibenz (a,j) acridine	OR	SHC AR	CN	15	500 mg/l		OU	In two cases, chemical was toxic or insignificantly oxidized after 144 hr. of oxidation. In a third case, chemical oxidation lagged at least 6 hr. after which it was slowly oxidized indicating a definite acclimation occurred. Up to 4.7% of TOD was exerted after 144 hr.	1b 2j 31 3q 4d 5e 5h 5t	Doubling MLSS to 5000 mg/l greatly improved oxidation after 6,24, and 144 hr. Up to 11.2% of TOD was exerted after 144 hr. of oxidation	44
1,2,5,6-Dibenz-anthracene	OR	HC AR		15	500 mg/l		OU	In 2 cases a degree of inhibition was apparent, but chemical was slowly oxidized. Up tc 7.9% of TOD exerted after 144 hr. of oxidation. In a third case, it was toxic or insignificantly degraded.	1b 2j 31 3q 4d 5e 5h 5t	Doubling MLSS to 5000 mg/l increased toxicity at 6 hr. and 24 hr. of oxidation and decreased the percentage of TOD exerted after 144 hr.	44

1	2	3	4	5	6	7	8	9	10	11	12
1,2,4,5-Dibenzpyrene	OR	HC AR		15	500 mg/1		OU	One sludge readily but slowly oxidized chemical; in other cases, chemical was toxic or not significantly oxidized after 144 hr. of oxidation.	1b 2j 31 3q 4d 5e 5h 5t	Doubling MLSS to 5000 mg/1 did not improve biological oxidation.	44
2,4-Dichlorophenol	OR WA	SHC AR	CO CX	12	64 ppm		CR	After 3 days of aeration removal increased rapidly. After 5 days, greater than 98% removal.	1c,2j 31,4a 5a,5b 5c,5e 5h,5i	Chemical mixed with aerated lagoon effluent and then subjected to continuous aeration; the decrease in conc. of chemical was monitored.	66
2,6-Dichlorophenol	OR WA	SHC AR	CO CX	12	64 ppm		CR	Chemical conc. decreased slowly during first 3 days of aeration then very rapidly thereafter. Greater than 99% removal resulted.	1c 2j 31 4a 5a 5b 5c 5e 5h 5i	Chemical was mixed with aerated lagoon effluent and then subjected to continuous aeration; the decrease in chemical conc. was monitored.	66

1	2	3	4	5	6	7	8	9	10	11	12
2,4-Dichlorophenoxyacetic Acid (2,4-D)	OR WA	SHC AR	CO CX	11	174 ppm		CR	No removal until after 5 days of aeration, then rapid removal to less than 2% of original concentration.	1c,2j 31,4a 5a,5b 5c,5e 5h,5i	Chemical was mixed with aerated lagoon effluent and then subjected to continuous aeration; the decrease in chemical conc. was monitored.	66
2,6-Dichlorophenoxyacetic Acid (2,6-D)	OR WA	SHC AR	CO CX	11	178 ppm		CR	Very little removal during first 3 days of aeration. Removal increased sharply during fourth day after which the conc. decreased very slowly. Approximately 30% removal.	1c,2j 31,4a 5a,5b 5c,5e 5h,5i	Chemical was mixed with aerated lagoon effluent and then subjected to continuous aeration; the decrease in chemical conc. was monitored.	66
2,4-Dichlorophenoxypropionic Acid	OR WA	SHC AR	CO CX	11	186 ppm		CR	After 7 days of aeration, there was no significant decrease in chemical conc.	1c,2j 31,4a 5a,5b 5c,5e 5h,5i	Chemical was mixed with aerated lagoon effluent etc., as above.	66

1	2	3	4	5	6	7	8	9	10	11	12
Dieldrin	OR	SHC AR	CO CX	11			OU CR	<5% of measured COD was utilized. Chemical was not significantly degraded.	4d 5c 5g	Insecticide.	53
Di(2-ethyl-hexyl)-phthalate	OR	SHC AR	CO	21		50% to 70%			1a,2i 3l,4c 5a,5b 5c,5d 5e,5h 5i,5k	Aerated lagoon treatment.	9
Di(2-ethyl-hexyl)-phthalate	OR	SHC AR	CO	21			OT	αvalue for 1 mg/l of chemical was 1.00, for 10 mg/l, α = 0.97.	1a,2i 3l,4c 5b,5d 5e,5g 5h,5i 5k	Completely mixed activated sludge process.	33
α,α'-Diethylstilbenediol	OR	SHC AR	CO	21	500 mg/l		OU	Inhibition or toxicity toward 2 of 3 sludges reflected by inhibition of oxygen uptake. One sludge slowly oxidized the chemical. Up to 5% of TOD exerted after 144 hr. of oxidation.	1b 2j 3l 3q 4d 5e 5h 5t	This and other carcinogenic compounds were generally resistant to biological oxidation.	44

1	2	3	4	5	6	7	8	9	10	11	12
Dimethylamine	OR WB	SHC NAR	CN	20	20 mg/l and 100 mg/l		CD	Increased chemical conc. resulted in increased chlorine demand. Contact time did not significantly affect chlorine demand.	1d 2j 3l 3p 4a 5e 5g	Probable products of chlorination of dimethylamine: 1)N-chlorodimethylamine 2)oxidation products	47
9,10-Dimethylanthracene	OR	AR HC		19	500 mg/l		OU	Readily, but slowly, biologically oxidized. Oxygen uptake was not inhibited. Up to 19.5% of TOD was exerted after 144 hr. of oxidation.	1b 2j 3l 3q 4d 5e 5h,5t	Not toxic, but very slowly oxidized. Doubling MLSS to 5000 mg/l did not affect degree of biological oxidation after 144 hr.	44
7,9-Dimethylbenz(c)-acridine	OR	SHC AR	CN	21	500 mg/l		OU	Toxic or insignificantly oxidized by 2 sludges. Third sludge readily, but slowly, oxidized chemical. Up to 4.1% of TOD exerted after 144 hr. of oxidation.	1b 2j 3l 3q 4d 5e 5h 5t	Doubling MLSS to 5000 mg/l improved oxidation of chemical after 6,24, and 144 hr.	44

1	2	3	4	5	6	7	8	9	10	11	12
7,10-Dimethyl-benz(c)-acridine	OR	SHC AR	CN	21	500 mg/l		OU	Chemical was toxic or showed insignificant oxidation after 144 hr of oxidation.	1b,2j 3l,3q 4d,5e 5h,5t	Doubling MLSS to 5000 mg/l greatly increased the degree of biological oxidation after 6,24, and 144 hr. of oxidation.	44
9,10-Dimethyl-1,2-benzanthracene	OR	AR HC		21	500 mg/l		OU	Readily, but very slowly, undergoes biological oxidation. Up to 12.7% of TOD exerted after 144 hr. of oxidation.	1b 2j 3l 3q 4d 5e 5h 5t	Doubling MLSS to 5000 mg/l did not significantly affect degree of biological oxidation after 144 hr. but oxidation after 6 hr. and 24 hr. was improved.	44
2,4-Dinitrophenol (contd.)	OR WA	SHC AR	CO CN	11	1 mg/l and 5 mg/l		OU	Increasing chemical conc. caused increased cumulative oxygen uptake after 120 hr. of aeration. However, maximum oxygen uptake rate at lower chemical conc. equalled maximum	1d 2j 3l 4d 5c 5e 5g 5h	Chemical conc. of 1 mg/l and 5 mg/l resulted in maximum SS conc. which were 2.2% and 10% less	65

1	2	3	4	5	6	7	8	9	10	11	12
2,4-Dinitro-phenol (contd.)								oxygen uptake rate of control, 27.7 ppm O_2/hr. At higher chemical conc. maximum oxygen uptake rate was 21.3 ppm O_2/hr.		respectively than the maximum conc. achieved in the control unit. In the chemical fed units the SS increased for 6 hr. and in the control the maximum SS conc. occurred at 10 hr.	
							COD	For 90% COD removal control required an aeration time of 7.5 hr.;lower chemical concentration required 15.0 hr.; and higher chemical conc. required 16.5 hr.			
							SS	Reduced SS production.			
2,4-D, isooctyl ester	OR	SHC AR	CO CX	11			OU CR	20% of measured COD was utilized. Chemical was materially degraded.	4d 5c 5g	Insecticide.	53
Dulcitol	OR	SHC NAR	CO	21	1.7%		OU	Slightly inhibited.	2h,31 4d,5e 5g,5h		15

1	2	3	4	5	6	7	8	9	10	11	2
Endrin	OR	SHC AR	CO CX	11			OU CR	<5% of measured COD was utilized Chemical was not significantly degraded.	4d 5c 5g	Insecticide .	53
Erucic Acid	OR WA	SHC NAR	CO	08	500 mg/1		OU	Oxidized, with 11% of TOD exerted after 24 hr. of oxidation.	1b 2j 31 3q 4d 5e 5g 5h 5t		49
1,2-Ethanediol (Ethylene glycol)	OR	SHC NAR	CO	21	484 mg/1		SVI	76.4 .	2j,3k 31,4a 5a,5b 5e,5g 5h,51 5t	With chemical as sole source of carbon or energy, a 1 to 3 hr. lag resulted before oxidation began.	52
							pH	Dropped 7.0 to 5.9 during 24 hr. of oxidation.			
							BOD	74% to 76% removed after 24 hr.			
							OU	48 mg of O_2 used in 24 hr.; this was about one-half the consumption of the control. Approximately 7.5% of of TOD exerted in 24 hr.			
							SS	Very slight increase.			

*Refer to Reference No. 15 for respirometer data.

1	2	3	4	5	6	7	8	9	10	11	12
Ethanol	OR	SHC NAR	CO	20		70% to 90%			1a,2i 3l,4c 5a,5b 5c,5d 5e,5h 5i,5k	Aerated lagoon treatment.	9
Ethanol	OR	SHC NAR	CO	20	1000 mg/l		SVI	61.0.	2j 3k 3l 4a 5a 5b 5e 5g 5h 5l 5t	Oxygen uptake did not show a lag period as occurred during aeration of methanol.	52
							pH	Drop from 6.9 to 6.0 during 24 hr.			
							SS	Increased by an average of 323 mg/l from an average initial conc. of 1734 mg/l.			
							BOD	Greater than 99% removal in 24 hr.			
							OU	After 24 hr. oxygen uptake was approximately 500 mg O_2 or 5 times that of the control. 24% of the TOD was exerted in 24 hr.			
Ethanol	OR	SHC NAR	CO	20		95% to 100%	OT	Ethanol conc. - αvalue 1 mg/l - 0.95 20 mg/l - 0.90 100 mg/l - 0.67	1a,2i 3l,4c 5b,5d 5e,5g 5h,5i 5k	Completely mixed activated sludge process; at 80% BOD reduction, achieved 99% chemical removal.	33

1	2	3	4	5	6	7	8	9	10	11	12
Ethyl Acetate	OR	SHC NAR	CO	20		90% to 100%			1a,2i 3l,4c 5a,5b 5c,5d 5e,5h 5i,5k	Aerated lagoon treatment.	9
Ethyl Acetate	OR	SHC NAR	CO	20		95% to 100%			1a,2i 3l,4c 5b,5d 5e,5g 5h,5i 5k	Completely mixed activated sludge process.	33
Ethyl Acrylate	OR	SHC NAR	CO	20		90% to 100%			1a,2i 3l,4c 5a,5b 5c,5d 5e,5h 5i,5k	Aerated lagoon treatment.	9
Ethyl Acrylate	OR	SHC NAR	CO	20		95% to 100%			1a,2i 3l,4c 5b,5d 5e,5g 5h,5i 5k	Completely mixed activated sludge process.	33

1	2	3	4	5	6	7	8	9	10	11	12
Ethylbenzene	OR	HC AR		18		90% to 100%			1a,2i 3l,4c 5a,5b 5c,5d 5e,5h 5i,5k	Aerated lagoon treatment.	9*
Ethylbenzene	OR	HC AR		18		95% to 100%			1a,2i 3l,4c 5b,5d 5e,5g 5h,5i 5k	Completely mixed activated sludge process.	33*
Ethylbenzene	OR	HC AR		18					1d 2j 3l,3p 4a 5e,5g	Removal by stripping and bio-oxidation.	47*
Ethylbenzene	OR	HC AR		18	105 mg/1		OU	After 72 hr. of oxidation 1.70 g of oxygen was utilized per gram of chemical added.	1b 2j 3l 4d 5b 5c 5e 5g 5h 5i 5k	Benzene derivatives studied in order of increasing toxicity: ethylbenzene, benzene, toluene, and n-propylbenzene.	29

*Refer to Reference No. 29 for additional data.

1	2	3	4	5	6	7	8	9	10	11	12
Ethyl-butanol	OR	SHC NAR	CO	20		30% to 50%			1a,2i 31,4c 5a,5b 5c,5d 5e,5h 5i,5k	Aerated lagoon treatment.	9
Ethyl-butanol	OR	SHC NAR	CO	20		95% to 100%			1a,2i 31,4c 5b,5d 5e,5g 5h,5i 5k	Completely mixed activated sludge process, at 80% BOD removal, achieved 95% chemical removal.	33
Ethylene or Propylene Glycol (Production Plant Wastewaters) (See also **1,2-Ethanediol, p. 85.**) **(contd.)**					Glycol concentration 500 to 1000 ppm. Other organics present in concentrations <100 ppm are the oxide, the dichloride, the chlorohydrin, and a chlori-		CR	All organic compounds of glycol wastewater are biodegradable by well acclimated cultures, except chlorinated ethers. These are toxic at >100ppm or in batch systems.	1a 2g 2j 31 3p 4a 4b 5a 5b 5e 5f 5h 5j 5k 5p 7a	Wastewater has high salt content (8 to 10% NaCl)and a pH of 11 to 12. Long acclimation period of 6-8 weeks required. Effluent contained metabolite and cell fragments which were removed	78
							BOD	Treatment efficiency is 86% at 12 hr. aeration (based on total oxygen demand) in batch reactor, 88% in continuous lab units and 84% in plug flow pilot plant.			

1	2	3	4	5	6	7	8	9	10	11	12
Ethylene or Propylene Glycol (Production Plant Wastewaters) (contd.)					nated ether May also contain acetol and acetic acid.			In completely mixed pilot plant 90% efficiency realized in 8-9 hr.		by chemical flocculation. Recycling activated sludge improved operating efficiency. Neutralization and nutrient addition are required.	
2-Ethylhexylacrylate	OR	SHC NAR	CO	20		90% to 100%			1a,2i 31,4c 5a,5b 5c,5d 5e,5h 5i,5k	Aerated lagoon treatment.	9
2-Ethylhexylacrylate	OR	SHC NAR	CO	20		95% to 100%			1a,2i 31,4c 5b,5d 5e,5g 5h,5i 5k	Completely mixed activated sludge process.	33
Ferbam®	OR ST	SHC NAR	CN CS	11			OU	Rapidly exerted 20% of measured COD.	4d 5c 5g	Fungicide.	53
							CR	Chemical was materiall degraded.			

1	2	3	4	5	6	7	8	9	10	11	12
2-Fluorenamine	OR	SHC AR	CN	21	500 mg/l		OU	Chemical showed inhibitory effect but was slowly biologically oxidized.	1b 2j 3l 3q 4d 5e 5h 5t		44
N-(2-Fluorenyl)-acetamide	OR	SHC AR	CN CO	21	500 mg/l		OU	Chemical was toxic to one sludge but slowly oxidized by 2 other sludges. Up to 12.3% of TOD exerted after 144 hr. of oxidation.	1b 2j 3l 3q 4d 5e 5h 5t		44
Fluoride	IN	NMC AN		03	33 mg/l	0%			1a 2g 3l 3p 4b 5a 5b 5c 5e 5h 5i 5k	No fluoride was removed in the aerated lagoon, increased temp. (>45°F utilized) and increased aeration time (>2.2 days utilized) will likely not improve removal.	37

1	2	3	4	5	6	7	8	9	10	11	12
Formaldehyde	OR	SHC NAR	CO	20	720 mg/l		OU	Chemical inhibited oxygen consumption. None of TOD exerted in 24 hr. of aeration.	2j,3k 3l,4a 5a,5b 5e,5g 5h,5l 5t	As formaldehyde was sole source of carbon or energy, it may have been toxic, not biodegradable or degradable only after a lag period longer than the duration of this study.	52*
Formaldehyde	OR	SHC NAR	CO	20	45 mg/l		CR	2-day lag period before oxidation.	1b 2j 3l 3p 3q 4d 5a 5b 5e	Increased formaldehyde conc. resulted in increased lag period before oxidation of the chemical and the other constituents in sewage began. Sludge could be acclimated to oxidize formaldehyde.	21
					90 mg/l and 100 mg/l		CR	3 day lag period before oxidation.			
					175 mg/l		CR	No oxidation.			
					750 mg/l		CR	Using acclimated sludge, oxidation rate leveled off at 5 hr.			
							BOD	12 hr. were required for 95% BOD removal.			
					1750 mg/l	95%	CR	Acclimation resulted in 95% removal in 24 hr.			
							pH	Oxidation resulted in decreasing pH.			
							SSR	Sludge settled well.			

*Refer to Reference No. 15 for respirometer and bottle test data.

1	2	3	4	5	6	7	8	9	10	11	12
Formaldehyde	OR	SHC NAR	CO	20	0 to 1500 ppm		OU	By buffering with $NaHCO_3$ conc. of formaldehyde up to 1000 mg/l were not toxic and 1500 mg/l only slightly inhibited biological activity.	1a 2j 31 4a 4c 4d 5a 5b 5c 5e 5g 5i 5k 5n		16*
					3000 ppm	>99%	CR	greater than 99% after 24 hr of aeration if pH held at 7.2.			
							BOD	lowering pH to 6.0 decreased BOD removal 12% but chemical removal remained the same.			
							pH	below pH 6 formaldehyde removal and BOD removal decreased.			
Formamide	OR	SHC NAR	CO CN	21	500 mg/l		OU	Chemical was readily, but slowly oxidized for 12 hr.; oxidation increased greatly from 12 hr. to 24 hr. with 11.8% of TOD exerted after 24 hr. of oxidation. Oxygen uptake increased rapidly during entire 24 hr. of study.	1b 2j 31 4d 5e 5g 5h 5t	Chemical showed greatest oxygen uptake of all amides studied. Propanamide followed closely in oxygen consumption.	49

* Refer to Reference No. 15 for respirometer and bottle test data.

1	2	3	4	5	6	7	8	9	10	11	12
Formic Acid	OR AC	SHC NAR	CO	15	720 mg/1		OU	Slightly stimulated oxygen consumption, 100 mg of O_2 consumed after 24 hr. oxidation compared to 75 mg by control. 40% of TOD exerted after 24 hr.	2j 3k,31 4a 5a,5b 5e,5g 5h,51 5t	Not attacked by pure culture zoogleal sludge.	52+
Formic Acid	OR AC	SHC NAR	CO	15	500 mg/1		OU	70% of TOD exerted after 24 hr. of oxidation. Chemical was readily oxidized.	1b,2j 31,3q 4d,5e 5g,5h 5i	No lag period during oxidation.	49
Fumaric Acid	OR WA	SHC NAR	CO	07	N/120		OU	Slightly stimulated.	2h,31 4d,5e 5g,51	Acid solution tested was neutralized to pH 7.	15
Glutamic Acid	OR AMP	SHC NAR	CO CN	07	500 mg/1		SVI	79.8.	2j 31 3k 4a 5a 5b 5e 5g 5h 51 5t	Chemical was sole source of carbon or energy and was readily oxidized.	52*
							pH	Increased from 6.8 to 6.9 during 24 hr. of oxidation.			
							SS	Increased by an average of 210 mg/1 from an initial average conc. of 1504 mg/1.			
							BOD	Almost 98% removal in 24 hr.			
(contd.)							OU	Slightly stimulated			

+ Refer to Reference No. 15 and 49 for respirometer and bottle test data.
* Refer to Reference No. 15 and 49 for respirometer data.

1	2	3	4	5	6	7	8	9	10	11	12
Glutamic Acid (contd.)								oxygen consumption. Up to 31% of TOD exerted in 24 hr.			
Glycerine	OR	SHC NAR	CO	21	720 mg/l		OU	248 mg of O_2 used in 24 hr, this was approximately 3 times the control. 28% of TOD exerted in 24 hr.	2j,3k 3l,4a 5a,5b 5e,5g 5h,5l 5t	Chemical was sole source of carbon or energy and was readily oxidized.	52
Glycine	OR AMP	SHC NAR	CO CN	07	720 mg/l		pH	Decreased from 7.2 to 6.5 during 24 hr. of oxidation.	2j 3l,3k 4a 5a,5b 5e,5g 5h,5l 5t	Chemical was sole source of carbon or energy and was readily oxidized.	52*
							SS	Increased by 728 mg/l.			
							BOD	Greater than 86% removal after 24 hr.			
							OU	Stimulated O_2 consumption from 2.5 to 5.6 times that of the control. Up to 58% of TOD exerted after 24 hr.			
Grease (contd.)	OR	SHC	CO	21	0.11 Lb per capita per day in raw sewage		CR	74% removal during secondary treatment.	1c 2g 3l 4c 5b 5c 5h	Forms of grease changed during treatment in a contact stabilization secondary	38+

*Refer to Reference No. 15 and 49 for respirometer data.
+Refer to Reference No. 46 for additional data.

1	2	3	4	5	6	7	8	9	10	11	12
Grease (contd.)										treatment plant. Fatty acids were predominant in the influent and compound lipids were predominant in effluent.	
Heptachlor	OR	SHC AR	CX	11			OU	5 to 20% of measured COD exerted.	4d 5c 5g	Insecticide.	53
							CR	Chemical was slightly degraded.			
n-Heptane	OR	HC NAR		18	500 mg/l		OU	Up to 38.7 % of TOD was exerted after 72 hr. of oxidation.	1b,2j 3l,3p 3q,4d 5e,5g 5h,5i 5t	Corresponding compounds having same number of carbon atoms in order of increasing toxicity were heptane, heptanoic acid, heptane-nitrile, and heptane-dinitrile.	43

1	2	3	4	5	6	7	8	9	10	11	12
n-Heptane	OR	HC NAR		18		90% to 100%			1a,2i 31,4c 5a,5b 5c,5d 5e,5h 5i,5k	Aerated lagoon treatment.	9*
n-Heptane	OR	HC NAR		18		95% to 100%			1a,2i 31,4c 5b,5d 5e,5g 5h,5i 5k	Completely mixed activated sludge process .	33*
1-Hexanol	OR	SHC NAR	CO	20		70% to 90%			1a,2i 31,4c 5a,5b 5c,5d 5e,5h 5i,5k	Aerated lagoon treatment.	9
1-Hexanol	OR	SHC NAR	CO	20		95% to 100%			1a,2i 31,4c 5b,5d 5e,5g 5h,5i 5k	Completed mixed activated sludge process. At 80% BOD removal, ca. 100% chemical removal was achieved.	33

* Refer to Reference No. 43 and 49 for nitrile and dinitrile respirometer data.

1	2	3	4	5	6	7	8	9	10	11	12
Hydracrylonitrile	OR	SHC NAR	CO CN	21		0 to 10%			1a,2i 3l,4c 5a,5b 5c,5d 5e 5h 5i,5k	Aerated lagoon treatment. Compound is possibly a biological intermediate	9
Hydrogen Cyanide	IN WA	Gas		22	500 mg/l		OU	Toxic at oxidation periods up to 72 hr.	1b 2j,3l 3p,3q 4d,5e 5g,5h 5i,5t		43
Hydrogen ion (H^+) (pH is the negative $\log_{10}$ of the hydrogen ion conc. in moles/liter.) (contd.)	IN	NMC CA					BOD	pH 7.0 to 7.5 produced best results; however, for pH 6.0 to 9.0 the results were very similar. Removal at pH 4.0 was 43% and at pH 10.0, 54%. System acclimated to to pH of 5.0 to 5.5 within about 1 week.	1b 2g 3l 3p 3q 4a 5a 5b 5e,5g 5h 5i 5l	Neutral pH range provided best conditions for activated sludge process.	30
							SS	Greatest removal occurred at pH 6.0 to 9.0, optimum removal at pH 7.0 to 7.5.			

1	2	3	4	5	6	7	8	9	10	11	12
Hydrogen ion (contd.)							SVI	A pH differing greatly from greatly reduced SVI.			
Hydrogen sulfide	IN WA	Gas		22	0.5 mg/l to 2.0 mg/l				6a	Causes corrosion above water level because it volatilizes and then condenses in moisture on walls. It is then converted bacterially to H_2SO_4.	46
4 - Hydroxybenzene - carbonitrile (p-Hydroxybenzonitrile)	OR	SHC AR	CN CO	21	500 mg/l		OU	Toxic after up to 72 hr of oxidation.	1b,2j 31,3p 3q,4d 5e,5g 5h,5i 5t	Aromatic mononitrile.	43
Iodide (I^-)	IN	AN		03	1 to 100,000ppm		OU	Concentrations greater than 10 ppm significantly inhibited O_2 uptake.	2h,31 4d,5e 5g,5h		15
Iodine, I^{131} (contd.)	IN	AN	RAS	16	0.01 to 10 mc		BOD	Reduced BOD_5 7% and the calculated	1b 31		23*

* Consult Reference No. 15 for respirometer data.

1	2	3	4	5	6	7	8	9	10	11	12
Iodine, I^{131} (contd.)								ultimate first stage BOD 11%.	5g		
							N	Inhibited.			
Iodine I^{131}	IN	AN	RAS	16	1 mg/l I^{127} and 0.5 μc I^{131}	1.4%	N	Inhibited at all I^{131} conc.	6a	Removal by activated sludge from synthetic sewage.	62*
					3 mg/l I^{127} and 0.5 μc I^{131}	2.7%					
					1 mg/l I^{127} and 0.5 μc I^{131}	10.3%				Removal by activated sludge from sewage.	
					3 mg/l I^{127} and 0.5 μc I^{131}	10.0%					
Iron (Ferrous, Fe^{+2})	IN	CA	HM	05	10 ppm to 1000 ppm		OU	Greater than 100 ppm caused significant inhibition of O_2 uptake.	2h,31 4d,5e 5g,5h	Less toxic than ferric iron.	15
Iron (Ferric, Fe^{+3}) (contd.)	IN	CA	HM	05	0.01 ppm to 100,000 ppm		OU	Greater than 100 ppm caused significant inhibition of O_2	2h,31 4d,5e 5g,5h	More toxic than ferrous iron.	15

* Refer to Reference No. 15 for respirometer data.

1	2	3	4	5	6	7	8	9	10	11	12
Iron (Fe^{+3}) (contd.)								uptake.			
Iron and Chromate Mixture	IN IN	CA MC AN	HM	05 05	100 ppm iron, 100 ppm chromate		OU	Mixture depressed O_2 uptake more than did either iron or chromate alone.	2h,31 4d,5e 5g,5h		15
Iron and Copper Mixture	IN IN	CA CA	HM HM	05 05	100 ppm iron, 10 ppm copper		OU	Mixture depressed O_2 uptake more than did iron alone, but less than did copper alone.	2h,31 4d,5e 5d,5h		15
Iron (See column # 6.)	IN	CA	HM	05	7.17 mg/l total iron, 0.60 mg/l total soluble Fe.	83% for total Fe, 62% for soluble Fe	BOD COD SS	Removal effeciency was similar to that for control unit.	1b 2g 31 4c 5a 5b 5c 5e 5h 5j 5k 5l 6a	Sulfuric Acid Pickle Liquor (ferrous sulfate) added to aeration to improve P removal. Unneutralized pickle liquor did not detrimentally affect the treatment plant or plant performance.	36
							MI	Not detrimentally affected.			
							pH	7.0 versus 7.1 for control.			
							SMC	Fe conc. of return sludge - 5% (dry basis).			
							VSS	Ash content of Fe fed unit increased.			
(contd.)							SDI	Slightly higher in Fe fed unit than in			

1	2	3	4	5	6	7	8	9	10	11	12
Iron (contd.)								control (1.04 versus 0.97).			
Isopropanol (2-Propanol)	OR	SHC NAR	CO	20		70% to 90%			1a,2i 31,4c 5a,5b 5c,5d 5e,5h 5i,5k	Aerated lagoon treatment.	9
Isopropanol (2-Propanol)	OR	SHC NAR	CO	20		95% to 100%			1a,2i 31,4c 5b,5d 5e,5g 5h,5i 5k	Completely mixed activa- sludge process. At 80% BOD removal, 96% chemical removal achieved.	33
Isopropanol (2-Propanol) (contd.)	OR	SHC NAR	CO	20					1d 2j 31 3p 4a 5e 5g	Substrate was completely degraded. Acetone was formed as an intermediate which was removed by bio-oxidation 50% and by stripping 50%	47

1	2	3	4	5	6	7	8	9	10	11	12
Isopropanol (2-Propanol) (contd.)										after longer aeration time.	
Isopropyl Ether (2-Isopropoxy-propane)	OR	SHC NAR	CO	20		70% to 90%			1a,2i 3l,4c 5a,5b 5c,5d 5e,5h 5i,5k	Aerated lagoon treatment.	9
Isopropyl Ether (2-Isopropoxy-propane)	OR	SHC NAR	CO	20		85% to 95%			1a,2i 3l,4c 5b,5d 5e,5g 5h,5i 5k	Completely mixed activated sludge process.	33
Lactic Acid	OR WA	SHC NAR	CO	07	720 mg/l		OU	Chemical greatly stimulated oxygen consumption. Up to 78% of TOD was exerted after 24 hr.	2j 3l,3k 4a 5a,5b 5e,5g 5h,5l 5t	Chemical was sole source of carbon or energy and was readily oxidized.	52*
Lactonitrile (contd.)	OR	SHC NAR	CN CO	21	139 mg/l		CR	75% of influent nitrogen as nitrile resulted in effluents containing 70% oxidized nitrogen (NO_2^- and NO_3^-). <5% of N removed in	1d 2l 3l 3p 4a 5a	Acclimation was necessary for significant chemioxidation.	41

* Refer to Reference No. 15 for respirometer data

1	2	3	4	5	6	7	8	9	10	11	12
Lactonitrile (contd.)								sludge.	5b 5c 5h 5i 5k 5n 5t		
					173 mg/l		CR	Similar to above.			
							G	System was unable to handle these conc. There was an increase in effluent NH_3-N and suspended solids, and a decrease in oxidized N.			
Lauric Acid	OR WA	SHC NAR	CO	08	500 mg/l		OU	Readily oxidized with 6.1% of TOD exerted after 24 hr. of oxidation.	1b 2j 3l 3q 4d 5e 5g 5h 5t		49
Lauric Acid Diethanolamide	OR	SHC NAR	CO CN	08			OU	69% of TOD exerted after 5 days, 85% of TOD exerted after 10 days of oxidation.	4d 5e 6a	Nonionic surfactant.	27
Lauric Acid Monoethanolamide (contd.)	OR	SHC NAR	CO CN	08			OU	72 % of TOD exerted after 5 days, 86% after 10 days of oxidation.	4d 5e 6a	Nonionic surfactant. Chemical showed slightly more degradation	27

1	2	3	4	5	6	7	8	9	10	11	12
Lauric Acid Monoethanolamide (contd.)										than lauric acid diethanolamide.	
Lead (Pb^{+2})	IN	CA	HM	05	1 to 100,000 ppm		OU	Significant inhibition occurred between 10 ppm and 100 ppm of lead.	2h,31 4d,5e 5g,5h		15
Lead (Pb^{+2})	IN	CA	HM	05	0.005 to 0.05 mg/l		MI	No stimulation or inhibition of growth.	1d 2k 3k 4a 5a	Growth of *Nitrosomonas* studied.	39
Lindane	OR	SHC AR	CX	11			OU	<5% of measured COD was utilized.	4d 5c 5g	Insecticide.	53
							CR	Chemical was not significantly degraded.			
Malathion	OR	SHC NAR	CO CS CP	11			OU	<5% of measured COD was utilized.	4d 5c 5g	Insecticide.	53
							CR	Chemical was not significantly degraded.			
Malic Acid	OR WA	SHC NAR	CO	07	N/120		OU	Stimulated.	2h,31 4d,5e 5g,5h	Acid solution tested was neutralized to pH 7.	15

1	2	3	4	5	6	7	8	9	10	11	12
L-Malic Acid	OR WA	SHC NAR	CO	07	500 mg/l		OU	Chemical was oxidized with 44.8% of TOD exerted after 24 hr. of oxidation. However in two cases an 8 hr. to 13 hr. lag was indicated.	1b,2j 31,3q 4d,5e 5g,5h 5t	Degradation of L-Malic acid was greater than for DL-Malic acid.	49
DL-Malic Acid	OR WA	SHC NAR	CO	07	500 mg/l		OU	Chemical was oxidized with 20.8% of TOD exerted after 24 hr. of oxidation. However, a 10 hr. to 16 hr. lag period was indicated.	1b,2j 31,3q 4d,5e 5g,5h 5t	DL-Malic acid was more refractory than L-Malic acid.	49
Malonic Acid	OR WA	SHC NAR	CO	07	N/120		OU	Stimulated.	2h,31 4d,5e 5g,5h	Acid solution tested by neutralized to pH 7.	15
Malonic Acid (contd.)	OR WA	SHC NAR	CO	07	500 mg/l		OU	Chemical inhibited oxygen uptake. At 6 hr. and 24 hr., 1.2% and 0.9%, respectively, of TOD was exerted.	1b,2j 31,3q 4d,5e 5g,5h 5t	The saturated di-carboxylic acids containing 2 to 8 carbon atoms were more resistant to biological	49

1	2	3	4	5	6	7	8	9	10	11	12
Malonic Acid (contd.)										oxidation than were the the corresponding mono-carboxylic acids. Most of the di-carboxylic acids were toxic.	
Maneb®	OR ST	SHC NAR	CS CN	11			OU	Chemical was rapidly oxidized with 20% of measured COD exerted.	4d 5c 5g	Fungicide.	53
							CR	Chemical was materially degraded.			
Manganese (Mn^{+2})	IN	SA	HM	05	12.5 to 100 mg/1		MI	Concentrations at which the following effects were observed: stimulation- 12.5-50 mg/1 inhibition- 50-100mg/1.	1d 2k 3k 4a 5a	Growth of Nitrosomonas studied.	39
Manganese (Mn^{+2})	IN	SA	HM	05	1 to 100,000 ppm		OU	Approximately 10 ppm caused significant inhibition of O_2 uptake.	2h,3l 4d,5e 5g,5h		15

1	2	3	4	5	6	7	8	9	10	11	12
Manganese and Cadmium Mixture	IN	SA	HM	05	100 ppm Manganese, 10 ppm cadmium		OU	The Mn-Cd mixture was more toxic or inhibitory than was either element individually.	2h,31 4d,5e 5g,5h		15
	IN	CA	HM	05							
Manganese and Zinc Mixture	IN	SA	HM	05	100 ppm manganese, 10 ppm zinc		OU	The Mn-Zn mixture was more toxic or inhibitory than was either element individually.	2h,31 4d,5e 5g,5h		15
	IN	CA	HM	05							
Mercury (Mercuric, Hg^{+2})	IN	CA	HM	05	0 to 200 mg/l		OU	Inhibitory effect indicated at 1 mg/l of chemical with complete toxicity at 200 mg/l.	1d 2j 31 3p 3q 4d 5a 5e 5f 5g 5h 5i	Chemical was not assimilated by the sludge organisms. Conc. measured as mercuric chloride, $Hg\ Cl_2$.	34
Mercury (Mercuric, Hg^{+2}) (contd.)	IN	CA	HM	05	1 to 10 mg/l		COD	Removal efficiency not affected by 1.0, 2.1, or 2.5 mg/l Hg^{+2}; however, 5.0 and 10 mg/l significantly retarded removal.	1d 2j 31 4a 5a 5c 5e 5f	Normal mercury conc. in raw sewage may be as high as 0.01 mg/l. A lag time was noted before	22
							COD	At 5 mg/l Hg^{+2}, removals after 30 min.			

1	2	3	4	5	6	7	8	9	10	11	12
Mercury (contd.)								and 1 hr., were 60% and 55% of that realized by the control and 10 mg/l Hg^{+2} 41% and 33% of the control. Removal by control after 3 hr. was 93%; by 5 mg/l fed unit - 86% after 5 hr; by 10 mg/l fed unit- 82% after 9 hr.	5g 5h 5i 6a	inhibition of COD, removal; an acclimation to 10 mg/l was noted with time. Threshold concentration occurred between 2.5 and 5 mg/l Hg^{+2}, with definite inhibition at doses > 5mg/l Threshold concentration was higher than reported in other literature, possibly because of a greater MLVSS concentration	
							OU	Doses of 1 to 2.5 mg/l Hg^{+2} had little detectable effect. 5 and 10 mg/l had a definite toxic or inhibitory effect; however, after 2 hr. the O_2 uptake rate for the 5 mg/l fed unit was > that of the control and after 4 hr. the rate for the 10 mg/l fed unit was greater than that for control.			
(contd.)							SP	Inhibitory effect of 5 and 10 mg/l of Hg^{+2} was most pronounced for first hour when		Mercury found to be more toxic to certain aquatic	

1	2	3	4	5	6	7	8	9	10	11	12
Mercury (contd.)								rate of growth was much slower than the control. After 5 hr., the MLVSS growth rate for 5 mg/l fed unit was 95% of control. For the 10 mg/l fed unit, 9 hr. was required for growth rate to reach 95% of control.		organisms than: Cu as $CuSO_4 \cdot 5H_2O$, Cd as $CdCl_2 \cdot 2\frac{1}{2}H_2O$, Zn as $ZnSO_4 \cdot 7H_2O$, Cr as $K_2Cr_2O_7$, & Pb as $PbCl_2$.	
							CR	51 to 58% reduction of soluble Hg^{+2} in the 5 mg/l and 10 mg/l Hg^{+2} fed units after 6 hr. Removed largely by adsorption or incorporation in cells, with possibly some volatilization.		27 mg/l $HgCl_2$ reported to cause 96% inhibition of respiration and 99% inhibition of aerobic oxidation and anaerobic fermentation in biological processes.	

1	2	3	4	5	6	7	8	9	10	11	12
Metals (as ions)	IN	SA	HM	0 5	1 to 10 mg/l		pH	Inhibition by metals is dependent on pH. Inhibition decreases markedly as pH increases from pH6 to pH8.		Order of decreasing toxicity: copper, lead, cadmium, zinc. The presence of appreciable concentrations of soluble sulfide and toxic concentrations of heavy metals are mutually exclusive. Sulfur compounds or ferrous sulfate continuously added should protect digestion process from occurrence of toxic concentrations of heavy metals.	51

1	2	3	4	5	6	7	8	9	10	11	12
Metals (as ions)	IN	SA	HM	05						Overgrowth of undesirable organisms in activated sludge process is connected with metal toxicity. When sewage bacteria are suppressed by presence of silver and nickel, the competition is in favor of Geotrichum candidum which takes over as predominant species.	55
Metals (as ions) (contd.)	IN	SA	HM	05			SO	Retarding effect occurred after prolonged periods of oxidation, rather than during the initial period.	6a	Order of decreasing toxicity: nickel, copper, chromic chromium, cadmium,zinc, cobalt, chromate chromium.	46

1	2	3	4	5	6	7	8	9	10	11	12
Metals (contd.)							M	Acidic pH markedly increased toxicity of all metals, especially copper and chromic chromium.			
Metals (as ions)	IN	SA	HM	04 05			SMC	1)Ag-0.03 to 0.27 mg/g 2)Al-4.4 to 32.2mg/g 3)Ba-0.7 to 3.0 mg/g 4)Be- not detected 5)Cd- not detected to 0.8 mg/g 6)Co- not detected 7)Cr-0.4 to 5.9 mg/g 8)Cu-0.9 to 6.0 mg/g 9)Fe-8.7to 27.4 mg/g 10)Hg-3.0 to 5.5μ/g 11)Mn-0.18 to 1.2 mg/g 12)Ni- not detected 13)Pb- 0.8 to 6.9 mg/g 14)Sr- not detected to 0.51 mg/g 15)V- not detected to 2.1 mg/g 16)Zn- 0.4 to 8.4 mg/g	1c 4c 6a	Aluminum and iron were found in greatest quantities in sewage sludges.	58

1	2	3	4	5	6	7	8	9	10	11	12
Metals (as ions)	IN	SA	HM	03 04 05			SMC	Average activated sludge metal content (mg per gram dried sludge): 1)Al - 10.0 2)As - 1.2 3)Ba - 1.15 4)Be - 0.0035 5)B - 0.07 6)Cd - 0.35 7)Ca - 13.0 8)Cr - 4.31 9)Co - 0.0016 10)Cu - 1.10 11)Fe - 40.5 12)Pb - 1.52 13)Mg - 7.04 14)Mn - 0.31 15)Hg - 0.016 16)Mo - 0.197 17)Ni - 0.378 18)P - 19.9 19)K - 4.21 20)Si - 39.5 21)Ag - 0.15 22)Na - 4.44 23)Sr - 0.155 24)S - 10.1 25)Sn - 0.5 26)Ti - 11.8 27)V - 0.7 28)Zn - 3.29 29)Zr - 10.0 30)Ga - 0.05.	1c 4c 6a	The following metal concentrations were greater in the activated sludge than in the primary sludge: 1)Al 2)Be 3)Cd 4)Cr 5)Fe 6)Pb 7)Hg 8)P 9)Na 10)Sr 11)Zr.	58

1	2	3	4	5	6	7	8	9	10	11	12
Metal Mixtures (Cyanide also present)	IN	SA	HM	05 13	0.79 mg/l Chromium, 0.21 mg/l Nickel, 0.43 mg/l Copper, 1.86 mg/l Zinc, 1.53 mg/l Cyanide		BOD	92% reduction.	6a	Metals became associated with sludge. Digested sludge contained metal concentrations 270 to 400 times greater than the raw sewage.	46
							SMC	Chromium concentration was 15 times greater than concentration in influent sewage; nickel, 12 times greater; copper, 19 times greater; zinc,28 times greater.			
							CR	Cyanide was almost completely removed.			
Metal Mixtures (Cyanide also present)	IN	SA	HM	05 13	0.4 mg/l Copper, 4.0 mg/l Chromium, 2.0 mg/l Nickel, 2.5 mg/l Zinc	App. 90% for Zinc 54% for Copper, 37% for Chromium 31% for Nickel at all the concentration	G	Little effect on aerobic process.	1b 2h 3l 3p 4b 5b 5c 5h 5i 5k	Total metal concentration 8.9 mg/l Total cyanide concentration 4.3 mg/l. Chromium removal was most variable because it is affected by dissolved oxygen in system. A nonsynergistic effect of combinations of metals was recognized.	12
							COD	Removal efficiency dropped 5%.			
							N	Almost completely inhibited.			
							DO	Mixed liquor and final effluent concentrations were higher than those of control unit.			
							SMC	Mixed liquor had affinity for metals in following order: zinc, copper, chromium, nickel.			
							SDI	Twice the control.			
							VSS	8% less than control.			
(contd.)											

1	2	3	4	5	6	7	8	9	10	11	12
Metal Mixtures (contd.) (Cyanide also present)						rations studied.					
					0.4 mg/l Copper, 2.0 mg/l Nickel, 2.5 mg/l Zinc		G	Little effect on aerobic process.		Total metal concentration =4.9 mg/l. Total cyanide concentration =4.3 mg/l.	
							COD	Removal efficiency dropped 5%.			
							N	Inhibited.			
							DO	Mixed liquor and final effluent concentration were higher than those of control unit.			
							SDI	Greater than twice the control.			
							VSS	5% less than control.			
					0.3 mg/l Copper, 0.5 mg/l Nickel, 1.2 mg/l Zinc		G	Borderline effect on aerobic process.		Total metal concentration =2.0 mg/l. Total cyanide concentration =2.0 mg/l. Effluent of metal-fed unit was lower in BOD and SS because of more efficient settling of the heavier sludge.	
							BOD SS	Removal was more efficient than occurred in the control unit.			
							SDI	60% greater than control.			
							VSS	3% less than control.			

1	2	3	4	5	6	7	8	9	10	11	12
Metal Mixtures	IN	SA	HM	05	1 to 9 mg/l		G	Total combined metal concentrations of up to 9 mg/l caused no serious reduction in aerobic or anaerobic processes.	1c,2i 3l,4c 5a,5b 5c,5h 5j,5k	Combination of metals - Chromium, Copper, Zinc, and Nickel.	5
Methanol	OR	SHO NAR	CO	20		30% to 50%			1a,2i 3l,4c 5a,5b 5c,5d 5e,5h 5i,5k	Aerated lagoon treatment.	9*
Methanol	OR	SHO NAR	CO	20	997 mg/l		pH	Decreased from 7.1 to 6.8 after 24 hr. of aeration.	2j 3k 3l 4a 5a 5b 5e 5g 5h 5l 5t	Oxygen uptake was 82% less than control after 24 hr. of aeration.	52*
							SS	Decreased an average of 172 mg/l from an average initial conc. of 2026 mg/l.			
							BOD	2.4% to 5.7% removed in 24 hr.			
							OU	36 to 41 mg O_2 used in 24 hr. 2.4% to 2.7% of TOD exerted in 24 hr.			
					500 mg/l		OU	110 mgO_2 used in 24 hr. 14.6% of TOD exerted. Oxygen uptake was 37% less than control after 24 hr.		There was a 3 hr. to 5 hr. lag period before O_2 consumption commenced.	

*Refer to Reference No. 47 for additional data.

1	2	3	4	5	6	7	8	9	10	11	12
Methanol	OR	SHC NAR	CO	20		75% to 85%			1a,2i 3l,4c 5b,5d 5e,5g 5h,5i 5k	Completely mixed activated sludge plant. At 80% BOD removal, achieved 84% chemical removal.	33*
7-Methyl-1,2 - benzanthracene	OR	HC AR		21	500 mg/l		OU	Inhibited oxygen uptake at least 24 hr. One sludge was capable of exerting 3.1% of TOD after 144 hr. of oxidation.	1b,2j 3l,3q 4d,5e 5h,5t	Chemical exhibited a toxic or inhibitory effect but was slowly oxidized in one case.	44
2-Methylbenzenecarbonitrile (o-tolunitrile)	OR	SHC AR	CN	15	500 mg/l		OU	Toxic at up to 72 hr. of oxidation.	1b,2j 3l,3p 3q,4d 5e,5g 5h,5i 5t	Aromatic mononitrile.	43
3-Methylbenzenecarbonitrile (m-tolunitrile)	OR	SHC AR	CN	15	500 mg/l		OU	Toxic at up to 72 hr. of oxidation.	1b,2j 3l,3p 3q,4d 5e,5g 5h,5i 5t	Aromatic mononitrile.	43

*Refer to Reference No. 47 for additional data.

1	2	3	4	5	6	7	8	9	10	11	12
4-Methylbenzene carbonitrile (p-tolunitrile)	OR	SHC AR	CN	15	500 mg/l		OU	Toxic at up to 72 hr. of oxidation.	1b,2j 31,3p 3q,4d 5e,5g 5h,5i 5t	Aromatic mononitrile.	43
20-Methylcholanthrene	OR	HC AR		19	500 mg/l		OU	Chemical showed both toxic or inhibitory effect, and the ability to undergo slow biological oxidation. Up to 9.3% of TOD exerted after 144 hr. of oxidation.	1b,2j 31,3q 4d,5e 5h,5t	Doubling MLSS to 5000 mg/l did not improve degree of biological oxidation after 144 hr.	44
Methyl-ethyl-pyridine	OR	SHC AR	CN	20		10% to 30%			1a,2i 31,4c 5a,5b 5c,5d 5e,5h 5i,5k	Aerated lagoon treatment.	9
Methyl Parathion	OR	SHC AR	CP CN CO CS	11			OU CR	Less than 5% of measured COD was utilized Chemical not significantly degraded.	4d 5c 5g		53

1	2	3	4	5	6	7	8	9	10	11	12
2-Naphthyl-amine	OR	SHC AR	CN	21	500 mg/1		OU	Toxic, oxygen uptake was inhibited by chemical.	1b,2j 31,3q 4d,5e 5h,5t	Introduction of amino group increased refractory nature of naphthalene.	44
Naphthalene	OR	HC AR		18		70% to 90%			1a,2i 31,4c 5a,5b 5c,5d 5e,5h 5i,5k	Aerated lagoon treatment.	9
Naphthalene	OR	HC AR		18		85% to 95%			1a,2i 31,4c 5b,5d 5e,5g 5h,5i 5k	Completely mixed activated sludge process.	33
Naphthalene	OR	HC AR		18	500 mg/1		OU	Inhibitory to oxygen uptake for up to 24 hr After 144 hr. of oxidation, up to 64.2% of TOD exerted.	1b,2j 31,3q 4d,5e 5h,5t	While naphthalene was degraded, 2-naphthalamine was toxic; introduction of amino group increased refractory nature.	44

1	2	3	4	5	6	7	8	9	10	11	12
Nickel (Ni^{+2})	IN	CA	HM	05	1 mg/l to 2.5 mg/l		G	Lowest continuous dose that causes an effect.	6a		46*
					50 mg/l to 200 mg/l		G	Lowest 4 hr. duration slug dose which would produce a 24 hr. effect on the effluent.			
					10 mg/l	28%	SMC	15% of added metal was found in the activated sludge and 2.5% was found in the raw sludge.			
Nickel (Ni^{+2})	IN	CA	HM	05	2.0 mg/l		SMC	12% of metal tied up in sludge.	1c 4c	Grand Rapids, Mich.	58
					0.03 mg/l		SMC	78% of metal tied up in sludge.		Richmond, Indiana.	
Nickel (Ni^{+2})	IN	CA	HM	05	0.05mg/l	0%	CR	Nickel passed through treatment plants in primarily a soluble form.	1c,2i 31,4c	Bryan, Ohio-overall removal.	5
					2.0 mg/l	10%			5a,5b 5c,5h	Grand Rapids, Mich.-overall removal.	
					0.03 mg/l	33%			5j,5k	Richmond,Ind-overall removal.	
					0.06 mg/l	20%				Bryan, Ohio-secondary removal.	
(contd.)					1.8 mg/l	0%				Grand Rapids, Mich.-secondary removal.	

*Refer to Reference No. 15 and 58 for additional data.

1	2	3	4	5	6	7	8	9	10	11	12
Nickel (contd.)					0.03 mg/l	33%				Richmond, Ind-secondary removal.	
Nickel (Ni^{+2})	IN	CA	HM	05	7 to 30 mg/l				6a	Nickel concentration increased slightly after chlorination of a municipal water supply.	1

1	2	3	4	5	6	7	8	9	10	11	12
Nickel (Ni^{+2})	IN	CA	HM	05	1 to 10 mg/l	28% to 42%	COD	Greater than 5 mg/l of Ni significantly reduced COD removal efficiency.	1b,2g 3l,3p 4b,5b 5c,5h 5i,5k	1 mg/l is near the threshold where the activated sludge process is affected.Nickel in final effluent is in solution. Effects of Ni did not increase linearly with increased chemical concentration, i.e., there is a plateau effect.	12
							T	Increased Ni concentrations caused increased turbidity.			
							SS	Activated sludge showed no affinity for Ni.			
							BOD	BOD removal decreased 5% at 5 mg/l and 10 mg/l Ni concentration.			
					25 mg/l and 50 mg/l		G	Slug doses over 4 hr. period did not greatly stress system.	1b,2h 3l,3p 4b,5b 5c,5h 5i,5k	Ni content of final effluent peaked 10 hr. after slug. After 8 hr., 60% of Ni in the final effluent was in solution. After 20 hr., all Ni in the effluent was in the soluble form.	
					200 mg/l		BOD COD T SS	Slug dose resulted in 4 times the normal effluent BOD concentration and 3 times the normal COD concentration. SS and turbidity were similarly affected. System returned to normal in 40 hrs.			

1	2	3	4	5	6	7	8	9	10	11	12
Nickel (Ni^{+2})	IN	CA	HM	05	200 mg/l		SAND	No effect on gas production.	1b,2h 3m,3p 4b,5b 5c,5h 5i,5k	Digested sludges had low soluble Ni concentrations due to the long detention time, high alkalinity, sulfide content and hydroxyl ion concentration.	12
Nickel (Ni^{+2})	IN	CA	HM	05	0.27 mg/l		CR	Primary sedimentation reduced Ni concentration about 20% and was unaffected by biological activity during sedimentation. Lime effectively removed Ni; aluminum sulphate did not improve removal; sulfuric acid completely suppressed removal. Activated sludge removed 30% of the Ni found in settled sewage. 70% passed out in effluent.	1b 2g 31 4c		60
Nickel (Ni^{+2})	IN	CA	HM	05	1 to 2.5 mg/l		G	Threshold limit before significant reduction in aerobic treatment efficiency.	1b,2g 31,4b		6
					50 to 200 mg/l		G	Will cause adverse effect.	1b,2h 31,4b	Slug dose over 4 hr.	

1	2	3	4	5	6	7	8	9	10	11	12
Nickel (Ni^{+2})	IN	CA	HM	05	10 mg/l	28%	SMC	2.5% of metal fed was found in primary sludge. 15% of metal fed found in excess activated sludge. 72% of metal fed found in final effluent.	1b,2h 31,4b	Activated sludge showed very poor removal of Ni with almost 75% passing straight through.	6
Nickel and Copper Mixture (ions)	IN IN	CA CA	HM HM	05 05	10 ppm nickel, 10 ppm copper		OU	Nickel-copper mixture was more toxic than was either nickel or copper alone.	2h,31 4d,5e 5g,5h		15
Nickel and Cyanide Mixture (ions)	IN IN	CA AN	HM	05 15	10 ppm nickel, 100 ppm cyanide		OU	Nickel-cyanide mixture was more toxic or inhibitory than nickel alone, but less toxic or inhibitory than cyanide alone.	2h,31 4d,5e 5g,5h	See Cyanide entry on p.21.	15
Nitriles (contd.)	OR	SHC	CN	15	500 mg/l				1b 2j 31 3p 3q 4d 5e 5g 5h 5i 5t	Mononitriles are toxic, inhibitory or very resistant to biological oxidation in 6 or 24 hrs. Refractory nature or toxic effect decreases with increasing chain length. Dinitriles are toxic, inhibitory or very resistant to	43

1	2	3	4	5	6	7	8	9	10	11	12
Nitriles (contd.)										biological oxidation for detention times up to 72 hr. Aromatic nitriles were all toxic. Presence of cyanide group reduces suspectibility of a molecule to biological oxidation. Acclimation of sludge did not improve nitrile removal.	
Nitriles	OR	SHC	CN	15	500 mg/l				1b,2j 3l,3q 4d,5e 5g,5h 5t	Cyanide replacing carboxyl grouping of saturated acid greatly reduced oxidizability, Mono- and dinitriles acted similarly. Acclimation of sludges to nitriles did not occur in 24 hr.	49

1	2	3	4	5	6	7	8	9	10	11	12
Nitriles	OR	SHC	CN	15	22 to 266 mg/1		CR	Nitrile reduction was generally good. Benzo- and adipo-nitrile were less toxic and more amendable to treatment than other nitriles studied.	1d 21 31 3p 4a 5a 5b 5c 5h 5i 5k 5n 5t	Nitriles studied included: 1) aceto- 2) adipo- 3) benzo- 4) acrylo- 5) lacto- 5) oxydipropio-. Ability to recover from over loads varied greatly with recovery to acrylonitrile the slowest. Recovery usually required 1-3 days. Cross acclimation to various nitriles existed in some cases.	41
							BOD	Removal was good; acetonitrile caused lowest BOD removal.			
							SP	Solids production varied; benzonitrile caused highest sludge production.			
							SDI	High (1.5 to 3.2) for all systems fed nitriles due to less efficient retention of lighter solids in clarifier.			
							MI	Nitriles inhibited fungi growth. Lactonitrile inhibited protozoan growth.			

1	2	3	4	5	6	7	8	9	10	11	12
Nitrilotri-acetate (NTA) (See also Trisodium Nitrilotri-acetate, p. 173.	OR	SHC NAR	CN CO	21	20 to 500 mg/l		COD SP SSR	Up to 200 mg/l of NTA showed no effect on these parameters.	1d 2g 2k 3l 3p 4a 5c 5e 5h	Presence of iron in a 1:1 ratio did not affect biodegradability of NTA. Acclimation period of 2-3 weeks was necessary for full chemical degradation in 6 hr. retention time.	64
							CR	>90% removal after acclimation (3 hr. and 6 hr. retention). Removal by adsorption onto sludge played, at most, a minor role in NTA removal.			
Nitrilotri-acetic Acid (NTA)	OR AC	SHC NAR	CO CN	21	Up to 110 mg/l		BOD	Oxygen requirement of NTA varied from 0.61 to 0.72 mg/l of O_2 per mg/l of NTA after 20 days of oxidation.	1d 2k 3k 4d	One week acclimation period was necessary before NTA was readily degraded.	54
							G	After acclimation, NTA did not affect performance of lab units.			
Nitrite	IN	NMC AN		04	1 to 100,000ppm		OU	Concentrations greater than 10 ppm significantly inhibited O_2 uptake.	2h,3l 4d,5e 5g,5h		15
Nitro-benzene	OR	SHC AR	CN CO	20	500 mg/l		OU	Toxicity reflected by inhibition of oxygen uptake for up to 144 hrs. of oxidation.	1b,2j 3l,3q 4d,5e 5h,5t		44

1	2	3	4	5	6	7	8	9	10	11	12
Nitro-benzene	OR	SHC AR	CN	20					1d 2j 3l 3p 4a 5e 5g	Complete removal of substrate primarily by biooxidation, with possibly some stripping. Possible formation of unidentified degradation product.	47
Nitro-benzene	OR	SHC AR	CN CO	20	500 mg/l		OU	Toxic or inhibitory during first 24 hr. of aeration.	1b,2j 3l,4d 5e,5g 5h,5i		45
2-Nitro-fluorene	OR	SHC AR	CO CN	21	500 mg/l		OU	Two sludges were able to readily, but slowly, oxidize the chemical; up to 13.7% of TOD was exerted after 144 hr. In a third case, the chemical was toxic.	1b,2j 3l,3q 4d,5e 5h,5t		44
Octyl Alcohol	OR	SHC NAR	CO	21		75% to 85%	OT	αvalue for 1 mg/l of chemical was 0.99; for 10 mg/l,α = 0.92.	1a,2i 3l,4c 5b,5d 5e,5g 5h,5i 5k	Completely mixed activated sludge process. At 80% BOD removal, 75% chemical removal was achieved.	33

1	2	3	4	5	6	7	8	9	10	11	12
Octyl Alcohol	OR	SHC NAR	CO	21		30% to 50%	-		1a,2i 31,4c 5a,5b 5c,5d 5e,5h 5i,5k	Aerated lagoon treatment.	9
p,tert-Octyl phenoxy-nonaethoxy-ethanol (OPE_{10}) (Triton X-100)	OR	SHC AR	CO	21	5 and 10 mg/1	>90%	CR	Degradation of OPE_{10} was associated with high loss of surfactant properties. There was no build up of OPE_{10} in the sludge.	1b 2g 21 31 4a 4c 5a 5b 5d 5e 5h 51 6a	Chemical was a nonionic surfactant. Extended aeration treatment process was utilized. Acclimation period of 2 weeks was noted in lab studies, but none was indicated in field work. Sludges acclimated to OPE_{10} were also capable of readily degrading other nonionic surfactants.	35
							G	Foaming problems did not occur.			
							BOD	Removals were not appreciably affected by OPE_{10} addition.			
							SVI	Not affected.			
							SP	An increase was noted.			

1	2	3	4	5	6	7	8	9	10	11	12
Oil Compounds							MI	Do not exhibit toxic or inhibiting effect on microorganisms.	1b 2j 3l 4b 4d 5b 5c 5e 5g 5h 5i 5k	Oils studied were: 1)crankcase oil 2)vegetable oil 3)refinery oil 4)crude oil 5)benzene derivatives a)benzene b)toluene c)ethyl benzene d)m-propyl benzene. Sludge density conditions control allowable loading of oil, especially with unacclimated sludge. Maximum safe oil loading was 5% of mixed liquor weight. Successive slug loads before system has returned to normal have a cumulative effect.	29
							CR	Materials were degraded to some degree.			
(contd.)							SSR	Compounds collect in floc and outside cell wall. Undesirable settling may be expected when oil content approaches 5% of MLSS in batch system; somewhat higher for continuous system. Settling problems developed at loading rates of 0.075 to 0.1 lb. of oil per lb. of sludge when sludge density was reduced below 1.016, the density of a well settling sludge.			

1	2	3	4	5	6	7	8	9	10	11	12
Oil Compounds (contd.)							OT	Was not influenced because floc adsorbed oily compounds before an interface impeding oxygen transfer developed.		Acclimated system can tolerate a loading of 0.1 lb. of hexane extractables per lb. MLSS.	
							TP	Effects were typical for biological systems.		Desirable to limit influent oil concentration to less than 50 mg/l. When lower levels of emulsificants occur aeration followed by gravity settling is sufficient. Where significant emulsification occurs, dissolved air flotation may be used. In extreme cases, chemical additives produce satisfactory effluents.	
							DT	Oil loading rate more directly controls system performance than does detention time.			

1	2	3	4	5	6	7	8	9	10	11	12
Oil, Crankcase (can contain heavy metals)					226 mg/l (185 mg/l hexane solubles)		OU	The O_2 uptake rate of 46 mg/l/hr. was slightly less than the rate of the control. 0.075 mg O_2 utilized per mg hexane extractables added.	1b,2j 3l,4b 5b,5c 5e,5g 5h,5i 5k		29
							BOD	Removal efficiency was similar to that for the control unit, >93%.			
Oil, Crude					82 mg/l (38 mg/l hexane solubles)		OU	The O_2 uptake rate of 50 mg/l/hr was the same as the rate of the control unit. 0.71 mg O_2 utilized per mg hexane extractable added.	1b,2j 3l,4b 5b,5c 5e,5g 5h,5i 5k		29
Oil, Mineral					1000 mg/l		SVI	39.3.	2j 3l 3k 4a 5a 5b 5e 5g 5h 5l 5t	Oxygen uptake was greatly inhibited.	52
							pH	Decreased from 7.1 to 5.5 during 24 hr. of aeration.			
							SS	Increased by an average of 244 mg/l from an average initial conc. of 2976 mg/l.			
							OU	Chemical greatly inhibited oxygen consumption. After 24 hr. of oxidation, the chemical fed unit consumed <one tenth the oxygen consumed by the control.			

1	2	3	4	5	6	7	8	9	10	11	12
Oil, Olive					916 mg/l		SVI	49.	2j,3l 3k,4a 5a,5b 5e,5g 5h,5l 5t	Oxygen consumption showed a lag for the first 3 hr.	52
							pH	Decreased from 6.9 to 6.1 during 24 hr. of aeration.			
							SS	Increased by an average of 448 mg/l from an initial average conc. of 3316 mg/l.			
							OU	Inhibited oxygen consumption to one-third to one-half the consumption of the control.			
Oil, Refinery					88 mg/l (44 mg/l hexane soluble)		OU	The O_2 uptake rate of 72 mg/l/hr was 44% greater than the rate of the control unit.	1b,2j 3l,4b 5b,5c 5e,5g 5h,5i 5k		29
							BOD	Removal efficiency was similar to that for the control unit, 94%.			
Oil, Vegetable					148 mg/l (132 mg/l hexane soluble)		OU	The O_2 uptake rate of 65 mg/l/hr was 30% greater than the rate of the control. 0.68 mg O_2 were used per mg hexane extractables added.	1b,2j 3l,4b 5b,5c 5e,5g 5h,5i 5k		29
							BOD	Removal efficiency was similar to that for the control unit, >94%.			

1	2	3	4	5	6	7	8	9	10	11	12
Oil, Emulsified					220 mg/l				6a	Oil, 200 mg/l phenol, and 250 mg/l sulfide from petroleum processing plant was satisfactorily treated by activated sludge.	46
Oil Refinery Wastewaters					Waste contained: oil-20ppm, phenol-11.4 ppm, H_2S- up to 15ppm		CR	Phenol removal exceeded 95%. Oil removal was >50%.	1a 2g 3l 3p 4c 5a 5b 5d 5h 5l	Phenol removal was >95% at following operating conditions: 1)ORP of +100 mv to +200 mv 2)D.O. of 1.5 to 3 ppm 3)pH of 6.0 to 8.5 4)suspended solids of 3000 to 11,000 ppm 5)SVI of 27 to 51 6)air supply of 900 cu.ft./lb. BOD removed.	74

1	2	3	4	5	6	7	8	9	10	11	12
Oleic Acid	OR WA	SHC NAR	CO	08	N/120		OU	Inhibited.	2h,3l 4d,5e 5g,5h	Acid solution tested was neutralized to pH 7.	15
Organic Acids	OR WA	SHC	CO	07 08	250 to 720 mg/l		CR	30% to 80% of the organic acids was removed by oxidation and 10% to 60% by conversion to protoplasm.	2j,3k 3l,4a 5a,5b 5e,5g 5h,5l 5t		52
Oxalic Acid	OR AC	SHC NAR	CO	07	250 mg/l		SVI	87.7.	2j 3k 3l 4a 5a 5b 5e 5g 5h 5l 5t	At 250 mg/l oxalic acid caused a negative oxygen consumption for 24 hr. of aeration. Increased chemical conc. resulted in less inhibition of oxygen uptake.	52*
							pH	Decreased from 7.2 to 6.9 during 24 hr. of aeration.			
							SS	Slight increase in concentration in 24 hr.			
							BOD	37.5% to 45% removed in 24 hr.			
							OU	Significantly inhibited oxygen consumption. None of the TOD was exerted after 24 hr.			
					720 mg/l		OU	Oxygen consumption was inhibited. After 24 hr. of aeration O_2 consumption was less than after 5 hr. of aeration; this was also true for the percentage of TOD exerted.			

*Refer to References No. 15 and 49 for respirometer data.

1	2	3	4	5	6	7	8	9	10	11	12
Oxalic Acid	OR AC	SHC NAR	CO	15	500 mg/l		OU	Oxygen consumption was inhibited for up to 24 hr of oxidation. After 6 hr. 4.5% of TOD exerted, after 12 hr., 0.4% was exerted.	1b,2j 31,3q 4d,3q 4d,5e 5g,5h 5t	Toxicity of chemical increased with increasing oxidation times.	49
Oxydipropionitrile	OR	SHC NAR	CN CO	15	113 to 170 mg/l		CR G	55% of influent nitrogen as nitrile resulted in effluent containing 75% oxidized nitrogen (NO_2 and NO_3). Removal in sludge was approximately 10%. Performance was good thus suggesting higher loadings could be handled.	1d,21 31,3p 4a,5a 5b,5c 5h,5i 5k,5n 5t	Acclimation was necessary for chemical oxidation. Length of acclimation period varied and increased with decreasing temperature. Dense floc was produced.	41
Paraldehyde	OR	SHC AR	CO	21		30% to 50%			1a,2i 31,4c 5a,5b 5c,5d 5e,5h 5i,5k	Aerated lagoon treatment.	9
Parathion	OR	SHC AR	CS CP CO CN	11			OU CR	<5% of measured COD was utilized. Chemical was not significantly degraded.	4d 5c 5g	Insecticide.	53

1	2	3	4	5	6	7	8	9	10	11	12
Pentachlorophenol	OR	SHC AR	CO CH	11	150 mg/l		OU	Oxygen utilization was at least 10% < that of the control after 300 min.	4d 5c 5g	Herbicide.	53
							CR	Substrate was not degraded.			
					75 mg/l		OU	< 5% of measured COD was utilized.			
							CR	Chemical was not significantly degraded.			
Pentaerythritol	OR	SHC NAR	CO	20	0 to 1000 ppm		OU	No toxic effect provided pH was maintained at 7.0.	1a,2j 3l,4a 4c,4d 5a,5b 5c,5e 5g,5i 5k,5n	Constituent of formaldehyde production wastewater.	16
Pentamethylbenzene	OR	HC AR		18	500 mg/l		OU	The chemical was toxic or inhibitory during first 24 hr. of aeration.	1b,2j 3l,4d 5e,5g 5h,5i		45
Pentanamide	OR	SHC NAR	CO CN	20	500 mg/l		OU	Readily, but slowly, oxidized for first 12 hr., more rapidly between 12 hr. and 24 hr., with 13.6% of TOD exerted after 24 hr. of oxidation.	1b 2j 3l 3q 4d 5e 5g 5h 5t		49

1	2	3	4	5	6	7	8	9	10	11	12
Pentane	OR	HC NAR		18	500 mg/l		OU	Pentane was oxidized by one sludge in 72 hr. (8.3% of TOD exerted) but was resistant or inhibitory to the two other sludges.	1b,2j 31,3p 3q,4d 5e,5g 5h,5i 5t	Corresponding nitrile had up to 18.1% of TOD exerted in 72 hr.; corresponding dinitrile was toxic; and corresponding monocarboxylic acid had up to 44.7% of TOD exerted after 72 hr. of oxidation.	43
Pentane-dinitrile	OR	SHC NAR	CN	15	500 mg/l		OU	The chemical was toxic at oxidation periods of up to 72 hr.	1b,2j 31,3p 3q,4d 5e,5g 5h,5i 5t	Dinitrile compound was toxic while corresponding nitrile had up to 18.1% of TOD exerted in 72 hr; the alkane (pentane) had 8.3% exerted; and the monocarboxyl acid (pentanoic or valeric acid) had up to 44.7% of TOD exerted in 72 hr. of oxidation.	43

1	2	3	4	5	6	7	8	9	10	11	12
Pentane-dinitrile	OR	SHC NAR	CN	15	500 mg/l		OU	Readily, but slowly, oxidized with 2.9% of TOD exerted after 24 hr. of oxidation. Oxygen uptake did not plateau but continued to increase throughout the 24 hr. of oxidation.	1b,2j 3l,3p 3q,4d 5e,5g 5h,5t	Chemical was oxidized more slowly than pentanenitrile.	49
Pentane-nitrile	OR	SHC NAR	CN	15	500 mg/l		OU	Toxic or inhibitory to two sludges at oxidation periods up to 24 hr. The chemical was appreciably oxidized by one sludge in 72 hr. (18.1% of TOD exerted).	1b,2j 3l,3p 3q,4d 5e,5g 5h,5i 5t	Mononitrile compound. Corresponding dinitrile was toxic at 72 hr. of oxidation, while the alkane (pentane) had up to 8.3% of TOD exerted; and the monocarboxylic acid (pentanoic) had up to 44.7% of TOD exerted in 72 hr.	43

1	2	3	4	5	6	7	8	9	10	11	12
Pentane-nitrile	OR	SHC NAR	CN	15	500 mg/l		OU	Readily but slowly, oxidized. Percent of TOD exerted was greater after 12 hr. of oxidation than after 24 hr. at 5.9% and 3.8% respectively. Oxygen uptake plateaued at approximately 18 hr.	1b,2j 31,3q 4d,5e 5g,5h 5t	Chemical was more rapidly oxidized than pentanedinitrile.	49
Peptone	OR	SHC	CN	21	720 mg/l		pH	Decreased from 7.4 to an average of 6.8 during 24 hr. of aeration.	2j,31 3k,4a 5a,5b 5e,5g 5h,51 5t	Both pure culture zoogleal sludge and activated sludge showed similar results.	52
							SS	Increased by 336 mg/l in 24 hr from an initial conc. of 2172 mg/l.			
							BOD	98% removal in 24 hr.			
							OU	O_2 uptake was greatly stimulated; chemical fed unit consumed 24 times more O_2 than the control.			
Petro-chemical Waste							OU	Increased from 0.2 lb. O_2/day/lb of MLVSS at <0.1 lb BOD removed/day/lb MLVSS to 0.9 lb O_2/day/lb. of MLVSS at 1.0 lb. of BOD removed/day/lb. of MLVSS.	6a	Oxygen consumption increased with increased organic loading.	75

1	2	3	4	5	6	7	8	9	10	11	12
Petro-chemical Wastewaters							CR	All organic compounds except 1,4-dioxane, 1,1,2-trichlorethane, 2-ethyl-1-hexanol, and acetophenone showed signigicant degrees of removal.	1a 2g 2h 3l 4c 5a 5b 5c 5d 5e 5f 5g 5h 5i 5k 5l	Waste contained following compounds: 1)diethyl ether 2)propylene oxide 3)acetone 4)ethyl acetate 5)isopropyl acetate 6)benzene 7)n-propyl acetate 8)toluene 9)1,4-dioxane 10)ethylbenzene 11)butanol 12)2-ethyl-1-hexylaldehyde 13)1,1,2-trichlorethane 14)1-hexanol 15)2-ethyl-1-hexanol 16)acetophenone 17)other unknowns. Shock loads caused reduction in oxidative capacity and sludge	76
							NB	Addition of H_3PO_4 was required.			
							SSR	Lack of phosphorus resulted in a poor settling sludge; addition of H_3PO_4 improved settleability.			
							SVI	Index was reduced to 75 to 100 ml/gm after addition of H_3PO_4; previously it was 400 to 700 ml/gm.			
(contd.)							BOD	Removal ranged from 70% to 84% with BOD loadings of 144 to 177 lb/ cu.ft./ day.			

1	2	3	4	5	6	7	8	9	10	11	12
Petrochemical Wastewaters (contd.)										settleability; temperature shocks had similar effects Chemicals of greatest concern in shock loads were: 1)alicylic unsaturated compounds 2)mercaptan and sulfone compounds 3)surfactants.	
Petrochemical Plant Wastewater				20			TP	Elevated temperatures of wastes are detrimental to microorganism flocculation and separation.	1a 2g 3m 4a 4b 5c 5e 5i 5k 5r 7a	Problems with aerobic, biological systems for treatment of these wastes are numerous; therefore anaerobic systems were studied.	77
							G	Surfactants caused foaming problems.			
							OU	Great oxygen demand often can not be satisfied, even at long retention times.			
							HRT	Long retention times are required for satisfactory removal efficiencies.			
(contd.)							N	Inhibited.			

1	2	3	4	5	6	7	8	9	10	11	12
Petrochemical Plant Wastewater (contd.)							SP	There were large volumes of sludge of which to dispose.			
Petrochemical Wastewater					Average COD- 2970 mg/l		SSR	Settleability decreased rapidly at loading rates >1.0 lb. COD/day/lb. MLSS.	1a 2g 3l 4a 5b 5c 5g 5k 7a	Waste was not inhibitory at organic loadings <0.8 lb. COD/day/lb.MLSS. Waste was not as rapidly degraded as domestic sewage fed at similar loading rates. Dehydrogenase measurement proved to be valid as a true sludge-activity parameter.	71
							BOD	Removal efficiency decreased steadily as organic loading increased from 98% at 0.1 lb. BOD/day/lb. solids to 63% at 1.5 lb. BOD/day/lb. MLSS.			
							COD	Removal efficiency paralleled BOD removal efficiency; however, highest efficiency was 72% at loading rate of 0.2 lb. COD/day/lb. MLSS.			
							SVI	Index increased rapidly for loading >1.2 lb. COD/day/lb. MLSS.			
							OU	O_2 consumption per gram of sludge increased with increased loading rates. Consumption was greater than for unit fed domestic waste.			
							DE	Enzyme activity closely related to O_2 uptake and increased as organic loading increased.			

1	2	3	4	5	6	7	8	9	10	11	12
Phenanthrene	OR	HC AR		19	500 mg/1		OU	Chemical was oxidized very slowly for first 72 hr. Up to 45.7% of TOD exerted after 144 hr. of oxidation.	1b,2j 31,3q 4d,5e 5h,5t		44
Phenol	OR	SHC AR	CO	12	200 mg/1	95%			6a	Activated sludge used to treat discharge from petroleum processing plant containing 220 mg/1 emulsified oil and 200 mg/1 phenol.	46
Phenol	OR	SHC AR	CO	12					1d,2j 31,3p 4a,5e 5g	Substrate was biologically oxidized in an acclimated system.	47

1	2	3	4	5	6	7	8	9	10	11	12
Phenol	OR	SHC AR	CO	12	10 mg/l and 20 mg/l		CD	Demand increased with increasing phenol concentration, and decreased with increasing chlorine application.	1d 2j 3l 3p 4a 5e 5g	Probable products of chlorination of phenol: 1)o-chlorophenol, 2)p-chlorophenol, 3)2,4-dichlorophenol, 4)2,6-dichlorophenol, 5)2,4,6-trichlorophenol, and 6)non-aromatic oxidation products.	47
Phenol	OR	SHC AR	CO	12	5 mg/l 18 mg/l	71% 62%	BOD	BOD removal efficiency was 58%.	1a,2g 3l,3p 4b,5a 5b,5c 5e,5h 5i,5k	Higher temperatures resulted in improved phenol removal.	37

1	2	3	4	5	6	7	8	9	10	11	12
Phenol (In Weak Ammonia Liquor)	OR	SHC AR	CO	12	10 to 30 lb.phenol/day/100 cu.ft. of aerator volume or 0.43 to 0.93 lb. of phenol per day/lb. of sludge in aerator.	greater than 99.8%			1b,2g 31,4b 5a,5e 5f,5h 5i	Weak ammonia liquor containing phenol was efficiently treated. Ammonia conc. greater than 2000 mg/l caused biological inhibition and decreased phenol oxidation rates. Thiocyanate removal varied. Complexed cyanides did not affect treatment. Nitrification did not occur.	32
Phenol	OR	SHC AR	CO	12	500 mg/l		OU	Up to 11.6% of TOD exerted after 72 hr. of oxidation.	1a,2j 31,3p 3q,4d 5e,5g 5h,5i 5j		43

1	2	3	4	5	6	7	8	9	10	11	12
Phenol	OR	SHC AR	CO	12	500 mg/1		OU	Uptake inhibited for first 24 hr. of oxidation. Up to 41.2% of TOD exerted in 144 hr.	1b,2j 31,3q 4d,5e 5h,5t	Acclimation of sludge after 24 hr. was indicated.	44
p-Phenylazoaniline	OR	SHC AR	CN	12	500 mg/1		OU	One sludge readily began to oxidize the chemical; however, after 72 hr. toxicity effect was evident by the inhibition of oxygen uptake.Second sludge demonstrated a 6 hr. lag period before oxidation. Chemical inhibited oxygen uptake by third sludge for up to 144 hr. of oxidation.	1b 2j 31 3q 4d 5e 5h 5t	Carcinogens were generally resistant to biological oxidation.	44
p-Phenylazophenol	OR	SHC AR	CO CN	12	500 mg/1		OU	Chemical toxic to one sludge. Another sludge readily began to oxidize chemical, but after 72 hr. toxicity was reflected by inhibition of oxygen uptake. Third sludge demonstrated 6 hr. lag period then slowly oxidized chemical; however, after 144 hr. of oxidation, oxygen transfer was inhibited.	1b 2j 31 3q 4d 5e 5h 5t	A small degree of biological oxidation was realized; however, lag periods were evident.	44

1	2	3	4	5	6	7	8	9	10	11	12
Phenylenediamine: m- o- p-	OR	SHC AR	CN	20	500 mg/l		OU	Toxic during 24 hr. of aeration.	1b,2j 3l,4d 5e,5g 5h,5i	Order of increasing toxicity: m-,o-,and p-phenylenediamine.	45
Phenyl Methyl Carbinol	OR	SHC AR	CO	20		85% to 95%			1a,2i 3l,4c 5b,5d 5e,5g 5h,5i 5k	Completely mixed activated sludge process.	33
Phosphorus, P^{32} (as PO_4^{-3}) (P^{32} is a radioactive isotope.)	IN	SA	RAS	16	10 mc/l		BOD	Biochemical oxidation was slightly inhibited in domestic sewage. Increasing P^{32} conc. to 80 mc/l caused no increase in inhibition.	1b 1d 3l 4d 5e 5g		59
					50 mc/l to 60 mc/l		BOD	Threshold concentration that significantly affects biochemical oxidation in synthetic sewage. In seeded synthetic sewage biochemical oxidation was not a first order reaction, but was stepwise.			

1	2	3	4	5	6	7	8	9	10	11	12
Phosphorus, p32 (as PO_4^{-3}) (P^{32} is a radioactive isotope; P^{31} is stable, i.e., non-radioactive.)	IN	SA	RAS	16	1 mg/1 p31 and 0.1μc p32	78% of p32			6a	Increasing radioactivity in synthetic sewage greatly decreased percent radioactivity removal. In sewage with none or low P^{32} and 3 mg/1 P^{31}, average removal of P^{31} varied somewhat, but stable P^{31} was preferentially removed vis-a-vis P^{32}.	62
					1 mg/1 p31 and 0.5μc p32	43% of p32					
					3 mg/1 p31 and 0.5μc p32	35% of p32					
Phosphorus, p32 (as PO_4^{-3})	IN	SA	RAS	16	10 mc/1		BOD	Reaction rate constant for oxygen utilization decreased.	1b 31 5g		23
							N	Sharply decreased.			

1	2	3	4	5	6	7	8	9	10	11	12
Phosphorus, P^{32} (as PO_4^{-3})	IN	SA	RAS	16			CR	Uptake of P^{32} was from 0.6 to 1.65 μc per gram of dry sludge.	6a	Amount of stabilized P^{31} affected P^{32} removal. When P^{31} was available it was favored over P^{32}.	62
					<10mc/l		BOD	No significant affect on BOD reaction-velocity coefficient (k), on the ultimate first stage BOD (L) and on BOD_5.			
					10 mc/l		N	Significant decrease.			
Polyethoxy-ethanol: 2-Ethoxy-ethanol and 2-[2-ethoxy-ethoxy]-ethanol	OR	SHC NAR	CO	20	100 ppm		OU	O_2 uptake was rapid in the presence of either chemical, but 2-[2-Ethoxy-ethoxy]-ethanol was slightly more resistant to degradation.	1b,2j 31,3p 4d,5b 5e,5g 5h,5i	Nonionic synthetic detergents. The ethoxy ether linkage did not block degradation.	11
Polyethoxy Fatty Ester: 1)Ethofat c/15 2)Ethofat c/60	OR	NAR	CO	21	100 ppm		OU	Resistance to biochemical oxidation increased with the size of the polyoxyethylene hydrophylic group. c/60 showed little increased oxygen utilization after 80 mins. of oxidation, while c/15 was more susceptible to oxidation.	1b 2j 31 3p 4d 5b 5e 5g 5h 5i	Nonionic synthetic detergents.	11

1	2	3	4	5	6	7	8	9	10	11	12
Polyvinyl-chloride Production Plant Wastewaters							BOD	Removal rate: 0.70 lb. BOD removed per lb. MLVSS.	1a 31 4c 7a	Wastewaters contain: monomers, polymers, organic and inorganic salts, organic acids, resins and fine rubber solids, dispersants, wetting agents, catalysts, and heavy metals. Waste requires pH adjustment and nutrient addition. Oxygen transfer reduced by surface active agents and dispersants. Latex solids cling to biological floc and cause stickiness and	10
							OT	Oxygen transfer coefficients: $\alpha = 0.5$ $\beta = 0.96$. O_2 requirement: 0.90 lb. O_2 applied per lb. BOD removed.			
							SP	0.68 lb. VSS produced per lb. BOD removed.			
							pH	7.0.			
							VSS	Suggested MLVSS--2500 mg/l.			
							NB	Waste is deficient in nitrogen and phosphorus.			
							HRT	Suggested - 6 hr.			
(contd.)											

1	2	3	4	5	6	7	8	9	10	11	12
Polyvinyl-cloride Production Plant Wastewaters (contd.)										extreme reduction in organic removal.	
Potassium Cyanide (See also: "Cyanide", p. 74.)	IN	CA AN		13	480 mg/l		OU	Oxygen consumption by chemical fed units was completely inhibited.	2j,31 3k,4a 5a,5b 5e,5g 5h,51 5t	As sole source of carbon or energy, material was toxic or resistant to biodegradation.	52
Propanedinitrile (Malonic Dinitrile)	OR	SHC NAR	CN	15	500 mg/l		OU	Toxic for oxidation periods up to 72 hr.	1b,2j 31,3p 3q,4d 5e,5g 5h,5i 5t	Toxicity of dinitrile was same as mononitrile having same number of carbon atoms; however, corresponding monocarboxylic acid (propanoic acid)had up to 45.8% of TOD exerted in 72 hr.	43

1	2	3	4	5	6	7	8	9	10	11	12
Propane-dinitrile (Malonic Dinitrile)	OR	SHC NAR	CN	15	500 mg/l		OU	Toxicity demonstrated by inhibition of oxygen uptake for oxidation periods up to 24 hr.	1b,2j 31,3q 4d,5e 5g,5h 5t	Most toxic dinitrile studied.	49
Propane-nitrile (Propio-nitrile)	OR	SHC NAR	CN	15	500 mg/l		OU	Toxic for oxidation periods up to 72 hr.	1b,2j 31,3p 3q,4d 5e,5g 5h,5i 5t	Chemical is a mononitrile compound. Toxicity of mononitrile was same as dinitrile having same number of carbon atoms however, corresponding monocarboxylic acid (propanoic acid) had up to 45.8% of TOD exerted in 72 hr.	43

1	2	3	4	5	6	7	8	9	10	11	12
β-Propiolactone	OR	SHC NAR	CO	20	500 mg/l		OU	Resistant to biological oxidation for up to 144 hr. Oxygen uptake was inhibited.	1b,2j 31,3q 4d,5e 5h,5t	One sludge became acclimated to chemical after 144 hr. and began to slowly oxidize the chemical.	44
n-Propylbenzene	OR	HC AR		20	37.5mg/l		OU	After 72 hr. of oxidation 0.67 g of O_2 were utilized per gram of substrate added.	1b,2j 31,4d 5b,5c 5e,5g 5h,5i 5k	Benzene derivatives studied in order of increasing toxicity or inhibition: ethylbenzene, benzene, toluene, n-propylbenzene.	29
Sodium Alkylbenzene Sulfonate (DobaneJN)	OR	SHC AR	CS	21			OU	26% of TOD exerted after 5 days, 32% after 10 days of oxidation.	4d 5e 6a	Anionic surfactant.	27

1	2	3	4	5	6	7	8	9	10	11	12
Sodium Alkyl Sulfonate (SAS)	OR	SHC NAR	" CS	21			OU	22% of TOD exerted after 5 days, 44% after 10 days of oxidation. None of the TOD was exerted in the first 6 hr.	4d 5e 6a	Anionic surfactant.	27
Sodium Aluminate	IN BA	MC		09					1b,2g 3l,3m 4c,5a 5h,5i 5k,5m 5s	Sludges containing precipitate formed by addition of the chemical dewatered more readily than did the control.	50
Sodium Lauryl Sulfate	OR	SHC NAR	CS	04			OU	65% of TOD exerted after 5 days, 68% after 10 days.	4d 5e 6a	Most readily degraded of the anionic surfactants studied.	27
Sodium N-Oleyl-N-Methyl Taurate	OR	SHC NAR	CO CS	04			OU	47 to 52% of TOD exerted in 5 days; 52 to 58% of TOD exerted after 10 days of oxidation.	4d 5e 6a	Anionic surfactant.	27

1	2	3	4	5	6	7	8	9	10	11	12
Sodium Pentachloro-phenate	OR-BA ST	SHC AR	CO CX	11	30 mg/l	68%	OU	Oxidation capacity of acclimated organisms reached a maximum of 68% in 25 days; afterwhich, the chemical may have accumulated to toxic levels as reflected by the loss of the ability to oxidize the chemical.	ld,2g 3p,4a 4d,5a 5e,5f 5i,6a	Biocide and wood preservative. A specially adapted mixed culture of organisms was capable of oxidizing the chemical.	31
Sodium Pentachloro-phenol (SPCP) (Sodium Pentachlorophenate)	OR-BA ST	SHC AR	CO CX	11	50 mg/l to 250 mg/l		CR	No chemical removal.	1b 2k 3l 3p 4a 5c 5e 5g 5h 5i 6a	Exposure for prolonged periods caused predominant species of microorganisms to change. Threshold limit for slug dose without severely upsetting COD removal was 20 mg/l.	26
							OU	Uptake was depressed slightly by increasing SPCP conc.; systems could be acclimated to 250 mg/l SPCP.			
							SSR	Sludge was dispersed and would not settle.			
							SP	Solids production decreased with increasing SPCP concentration.			
					15 mg/l		COD	Unit receiving a slug dose required twice the aeration time of the control to achieve comparable COD removal.			
							CR	No chemical removal.			
					30 mg/l		G	Slug dose drastically reduced efficiency.			

1	2	3	4	5	6	7	8	9	10	11	12
Sodium α-Sulfo Methyl Myristate	OR ST	SHC NAR	CS CO	04			OU	33% of TOD exerted after 5 days; 47% of TOD exerted after 10 days of oxidation.	4d 5e 6a	Anionic surfactants studied were more resistant to biodegradation than the nonionic surfactants studied.	27
Strontium (Sr^{+2})	IN	CA	HM	05	0.005 to 0.05 mg/l		MI	No stimulation or inhibition of growth.	1d 2k 3k 4a 5a	Growth of Nitrosomonas studied.	39
Styrene	OR	SHC AR		18		70% to 90%			1a,2i 3l,4c 5a,5b 5c,5d 5e,5h 5i,5k	Aerated lagoon treatment.	9
Styrene	OR	SHC AR		18		95% to 100%			1a,2i 3l,4c 5a,5b 5e,5g 5h,5i 5k	Completely mixed activated sludge process.	33

1	2	3	4	5	6	7	8	9	10	11	12
Sulfate (SO_4^{-2})	IN	NMC AN		03	300 mg/l or greater				6a	Corrode submerged concrete even at neutral pH. Corrosion accelerated by biological action.	46*
Sulfide (S^{-2})	IN	NMC AN		04	250 mg/l	100%			6a	Activated sludge used to treat discharge from petroleum processing plant containing sulfide, 200 mg/l phenol, and 220 mg/l emulsified oil.	46*
(contd.)					25 mg/l to 50 mg/l		G	Reduction in efficiency of aerobic process but acclimation allowed purification at 25 mg/l to 50 mg/l. These conc. can be tolerated for about			

* Refer also to Reference No. 15 for respirometer data.

1	2	3	4	5	6	7	8	9	10	11	12
Sulfide (contd.)								1 week.			
Sulfite (SO_3^{-2})	IN	NMC AN		04	500 mg/l				6a	Activated sludge may be acclimated to oxidize up to 500 mg/l sulfite-sulfur, but increased oxygen is required.	46*
Sulfite Liquor					BOD of 608 mg/l		SP	0.4-0.5 lb. solids produced per lb. BOD removed.	1a 2g 3l 4a 4b 5a 5b 5e 5h 5i 5k 6a 7a	Wastewater required neutralization for optimum treatment.	14
							BOD	At initial BOD of approximately 608 mg/l 80% reduction was achieved at optimum pH. Below pH 6.0 and above pH 7.5, BOD removal efficiency decreased sharply. Over temperature range of 16°C-27°C there was no significant differ-			
(contd.)											

* Refer also to Reference No. 15 for respirometer data.

1	2	3	4	5	6	7	8	9	10	11	12
Sulfite Liquor (contd.)								ence in BOD removal efficiency.			
Sulfite Waste Liquor							TP	Adaptation of activated sludge to temperature change was immediate. Fluctuations between 10°C and 30°C at 12 hr. intervals was not detrimental to sludge quality.	1a 2g 31 4a 5a 5b 5e 5i 5k 5s	Acidic waste was successfully treated. Although pH of 5 to 11 was acceptable, BOD removal was most efficient at ca. neutral pH, i.e., pH=7. The temperature fluctuations were not detrimental to sludge quality, but BOD removal was more efficient at 30 °C than at 10 °C.	32
							pH	Effects of pH are a function of temperature. Increasing temperature from 10° to 30°C greatly minimized the detrimental effect of pH 5. Activated sludge can treat wastes with pH range of 5 to 11 provided acid formation does not depress pH below 5.			
(contd.)							G	Sludge could be starved at least 3 weeks without			

1	2	3	4	5	6	7	8	9	10	11	12
Sulfite Waste Liquor (contd.)								seriously impairing purification capacity. Treatment efficiency returned to normal 2-5 days after resumming full load.			
Spent Sulfite Liquor					0.3 to 0.7 percent of feed		SSR	The spent sulfite liquor: (SSL) 1) inhibited large protozoan forms, 2) caused F:M ratios to rise with increasing SSL concentrations, and 3) interfered with biological flocculation.	1a 2g 3l 3p 4a 4b 4c 5a 5b 5d 5e 5f 5h 5i 6a 7a	BOD loading composed primarily of volatile organic acids lignosulfonates, and wood sugars. The typica pH of 3.0 required neutralization with lime to pH 7.0 to 7.4 to optimize biological flocculation, sludge production, and costs.	7
							SVI	Bulking (described as an SVI > 125) occurred primarily due to a deficiency of phosphorus in the wastewater.			
Surfactants, Nonionic and Anionic (contd.)	OR	SHC		04					4d 5e 6a	Nonionic surfactants studied showed greater	27

1	2	3	4	5	6	7	8	9	10	11	12
Surfactants, Nonionic and Anionic (contd.)										biodegradation than did the anionic surfactants studied.	
Surfactant (Nonionic, NPX®)	OR	SHC NAR	CO	04			OT	α value for 3 mg/l of chemical is 0.96; for 10 mg/l, α = 0.90.	1a,2i 3l,4c 5b,5d 5e,5g 5h,5i 5k	Completely mixed activated sludge process.	33
Tannic Acid	OR WA	SHC NAR	CO	08	N/120		OU	Inhibited.	2h,3l 4d,5e 5g,5h	Acid solution tested was neutralized to pH 7.	15
Tetraethyl Pyrophosphate (TEPP)	OR	SHC NAR	CO CP	11			OU	<5% of measured COD was utilized.	4d 5c 5g	Insecticide.	53
							CR	Chemical was not significantly degraded.			
1,2,4,5-Tetramethylbenzene (Durene ®) (contd.)	OR	HC AR		20	500 mg/l		OU	No oxygen consumed during first 3 hr., very slight uptake thereafter for first 24 hr. of aeration.	1b 2j 3l 4d 5e 5g		45

1	2	3	4	5	6	7	8	9	10	11	12
1,2,4,5-Tetramethylbenzene (Durene ®) (contd.)									5h 5i		
Thanite ® (Isobornyl thiocyanoacetate)	OR	SHC AR	CO CN CS	11			OU	Chemical was rapidly oxidized with 20% of COD exerted.	4d 5c 5g	Insecticide.	53
							CR	Chemical was materially degraded.			
Thioacetamide	OR	SHC NAR	CS CN	21	1000 mg/l		SVI	76.0.	2j 3l 3k 4a 5a 5b 5e 5g 5h 5l 5t		52
							pH	Decreased from 6.9 to 6.7 during 24 hr. of aeration.			
							SS	Increased by an average of 84 mg/l from an initial conc. of 1768 mg/l.			
							OU	Oxygen consumption by chemical fed units was completely inhibited.			

1	2	3	4	5	6	7	8	9	10	11	12
Thiocyanate (SCN$^-$)	IN	AN		04	0.01 to 100,000 ppm		OU	Greater than 1000 ppm significantly inhibited uptake while <1000 ppm slightly stimulated uptake.	2h,31 4d,5e 5g,5h		15
Thioglycollic Acid	OR AMP	SHC NAR	CO CS	07	662 mg/l		SVI	76.0.	2j 31 3k 4a 5a 5b 5e 5g 5h 51 5t	Oxygen consumption decreased with increased oxidation time. As material was sole source of carbon or energy, results indicated that the material was toxic or resistant to biodegradation.	52
							pH	Decreased from 6.8 to 6.4 after 24 hr. of aeration.			
							SS	Decreased by an average of 44 mg/l from an average initial conc. of 1780 mg/l.			
							OU	Oxygen consumption decreased with time and was completely inhibited within 24 hr. Up to 4.5% of TOD exerted in first hour but the percent TOD exerted decreased with time.			
2-Thiouracil (contd.)	OR	SHC NAR	CS CO CN	21	500 mg/l		OU	Chemical was oxidized, but very slowly, by 2 of 3 sludges. There was no lag period before oxidation	1b 2j 31 3q 4d	Up to 12.8% of TOD exerted after 144 hr. of oxidation.	44

1	2	3	4	5	6	7	8	9	10	11	12
2-Thiouracil (contd.)								commenced.	5e 5h 5t		
Thiourea	OR	SHC NAR	CS CN	21	500 mg/l		OU	Oxygen uptake was inhibited by chemical for up to 144 hr. of oxidation.	1b,2j 3l,3q 4d,5e 5b,5t	Up to 5.7% of TOD was exerted by one of three sludges after 144 hr. of oxidation.	44
Toluene	OR	HC AR		18		70% to 90%			1a,2i 3l,4c 5a,5b 5c,5d 5e,5h 5i,5k	Aerated lagoon treatment.	9
Toluene	OR	HC AR		18		95% to 100%			1a,2i 3l,4c 5b,5d 5e,5g 5h,5i 5k	Completely mixed activated sludge process.	33
Toluene	OR	HC AR		18	500 mg/l		OU	Inhibitory or very slightly oxidized for first 24 hr. of oxidation. Up to 54% of TOD exerted after 144 hr.	1b 2j 3l 3q 4d 5e 5h 5t		44

1	2	3	4	5	6	7	8	9	10	11	12
Toluene	OR	HC AR		18			CR	In biological degradation studies of acclimated systems, toluene was removed by stripping and biooxidation.	1d 2j 3l 3p 4a 5e 5g		47
Toluene	OR	HC AR		18	100 mg/l		OU	After 72 hr. of oxidation, 0.53 to 0.65g. of O_2 were utilized per g. of substrate added.	1b 2j 3l 4d 5b 5c 5e 5g 5h 5i 5k	Toluene caused more inhibition of oxygen consumption than did benzene, ethylbenzene, but less than n-propylbenzene.	29
Toluene	OR	HC AR		18	500 mg/l		OU	Up to 48.3% of TOD exerted after 72 hr. of oxidation.	1b,2j 3l,3p 3q,4d 5e,5g 5h,5i 5t		43

1	2	3	4	5	6	7	8	9	10	11	12
m- Toluidine o- p-	OR	SHC AR	CN	20	500 mg/1		OU	o- Toluidine was slightly toxic during 24 hr. aeration, while m- and p- Toluidine were slightly oxidized and more toxic.	1b 2j 31 4d 5e 5g 5h 5i	Order of increasing toxicity: m-, p-, and o-toluidine.	45
2,4,6- Trichloroaniline	OR	SHC AR	CH CN	21	up to 10 mg/1		OU	Not inhibited.	1d 2j 31 4d 5e 5g	Solubility prevented investigations at higher concentrations.	47
2,4,5-Trichlorophenol	OR	SHC AR	CO CX	11			OU	5-20% of ultimate BOD was exerted.	4d 5c 5g	Fungicide and bactericide.	53
							CR	Chemical was slightly degraded.			
2,4,5- Trichlorophenol (contd.)	OR	SHC AR	CO CX	11	18.8 ppm		CR	Chemical concentration decreased slowly for 4 days, then decreased very rapidly. At 6.5 days, greater than 99% removal was realized.	1c 2j 31 4a 5a 5b 5c 5e 5h 5i	Chemical was mixed with aerated lagoon effluent and then subjected to continuous aeration; the decrease in chemical concentration	66

1	2	3	4	5	6	7	8	9	10	11	12
2,4,5- Tricholorophenol (contd.)										was monitored.	
2,4,6- Trichlorophenol	OR	SHC AR	CO CX	11	1 mg/l to 10 mg/l		OU	No inhibitory effect.	1d 2j 3l 4d 5e 5g		47
					50 mg/l to 100 mg/l		OU	Significant inhibition.		Effect of the chemical was similar to the effect of 1 mg/l to 10 mg/l copper.	
2,4,6- Trichlorophenol	OR	SHC AR	CO CX	11	18.5 ppm		CR	Chemical concentration decreased slowly for 1 day, then very rapidly until third day and then slowly until fifth day. Overall removal was greater than 99%.	1c 2j 3l 4a 5a 5b 5c 5e 5h 5i	Chemical was mixed with aerated lagoon effluent and then subjected to continuous aeration; the decrease in chemical conc. was monitored.	66
2,4,5- Trichlorophenoxyacetic Acid (2,4,5-T) (contd.)	OR WA	SHC AR	CO CX	11	150 mg/l		OU	5-20% of ultimate BOD was exerted.	4d 5c 5g	Herbicide.	53
							CR	Chemical was slightly degraded.			

1	2	3	4	5	6	7	8	9	10	11	12
2,4,5- Trichlorophenoxyacetic Acid(2,4,5-T) (contd.)					75 mg/l		OU	20% of ultimate BOD was exerted.			
							CR	Chemical was materially degraded.			
2,4,5- Trichlorophenoxyacetic Acid (2,4,5-T)	OR WA	SHC AR	CO CH	11	50 ppm		CR	Chemical concentration decreased slightly for 5 days, then decreased very rapidly. After 7.5 days greater than 99% removal was realized.	1c 2j 31 4a 5a 5b 5c 5e 5h 5i	Chemical was mixed with aerated lagoon effluent and then subjected to continuous aeration; the decrease in chemical concentration was monitored.	66
2,4,6- Trichlorophenoxyacetic Acid (2,4,6-T)	OR WA	SHC AR	CO CH	11	53.0 ppm		CR	Chemical concentration decreased steadily during 14 days of aeration. Overall removal was approximately 50%.	1c 2j 31 4a 5a 5b 5c 5e 5h 5i	Chemical was mixed with aerated lagoon effluent and then subjected to continuous aeration; the decrease in chemical conc. was monitored.	66

1	2	3	4	5	6	7	8	9	10	11	12
2,4,5- Trichlorophenoxypropionic Acid	OR WA	SHC AR	CO CX	11	107.5 ppm		CR	Conc. remained constant for 2 days then decreased rapidly until 14.5 days and then slowly to 16.5 days. Overall removal was approximately 99%.	1c 2j 3l 4a 5a 5b 5c 5e 5h 5i	Chemical was mixed with aerated lagoon effluent and then subjected to continuous aeration; the decrease in chemical conc. was monitored.	66
1,2,4-Trimethylbenzene (Pseudocumene)	OR	HC AR		18	500 mg/l		OU	Toxic or inhibitory for at least first 18 hr.; after 18 hr. material was slightly oxidized.	1b 2j 3l 4d 5e 5g 5h 5i		45
2,4,6- Trinitrotoluene (TNT)	OR	SHC AR	CN	20	5 to 25 mg/l	50% to 84%	BOD	Sample with greatest color exerted lowest BOD; waste with greatest color showed greatest bio-toxicity.	1a 4a 4e 5a 5b 5c 5e 5h 5i 5u	TNT wastes were found to contain the following isomers: 1) 2-MNT - 0.32 to 16.5 mg/l 2) 3-MNT - 1.1 mg/l	25
							G	Color removal during activated sludge treatement of TNT wastes averaged 3%.			
(contd.)							CR	Removal of the chemi-			

1	2	3	4	5	6	7	8	9	10	11	12
2,4,6- Trinitrotoulene (TNT) (contd.) (contd.)								cal varied from 50% to 84%. Increasing chemical conc. resulted in decreased removal. Detention times of 3 hr. and 7 hr. showed essentially same removals, while a 14 hr. detention time improved removal by 6 to 18%.	6a 7a	3) 4-MNT - 0.12 to 9.2 mg/l 4) 2,6-DNT - trace to 38.8 mg/l 5) 2,4-DNT - 3.39 to 56.3 mg/l 6) 2,4,6-TNT-101 to 142.9 mg/l 7) TNBA (trinitrobenzoic acid) - 0 to 0.80 mg/l. Total isomer concentration was 147 to 259 mg/l. Wastewater characteristics: 1) pH-2 2) color - 200 color units	

1	2	3	4	5	6	7	8	9	10	11	12
2,4,6- Trinitrotoulene (TNT) (contd.)										3) temp - 95°F 4) TNT (as α TNT) - 100 mg/1 5) COD - 250 mg/1 6) NO_3-N - 200 mg/1 7) SO_4 - 1000 mg/1 8) total solids - 2000 mg/1.	
Trisodium Nitrilotriacetate (NTA) (See also Nitrilotriacetate, p. 128). (contd.)	OR ST	SHC NAR	CO CN	09	1 mg/1 to 50 mg/1	90% to 100%	G	No effect on treatment efficiency.	1b 1d 2g 2h 2j 3l 3m 3p 3q 4a 4e 5a 5b 5c 5e 5h	NTA is a chelating material. With fresh sludge, a 2 to 21 day acclimation period occurred before degradation began.	67
							SSR SVI	Characteristics of NTA fed units were similar to those of the control.			
							CR	Acclimated sludges showed virtually complete removal of 1 to 30 mg/1 of NTA in 4 to 7 hr. of aeration.			
							COD	At 30 mg/1 NTA, COD removal effeciency was similar to that of the control unit.			

1	2	3	4	5	6	7	8	9	10	11	12
Trisodium Nitrilotri-acetate (NTA) (contd.)					20 mg/l to 500 mg/l		CR	Degradation was complete in 3 hr. and 6 hr. of aeration.	5l 5m 5t 6a		
					up to 200 mg/l		G	No upsets in normal function of activated sludge.			
					1.5 mg/l and 15 mg/l		SSR	NTA did not affect settling of primary sludge.			
Tyrosine	OR AMP	SHC AR	CO CN	08	500 mg/l		SVI	53.2.	2j 3l 3k 4a 5a 5b 5e 5g 5h 5l 5t	Oxygen consumption lagged for at least the first 3 to 5 hr., but the material was the sole source of carbon or energy and was susceptible to biodegradation.	52*
							pH	Decreased from 6.6 to 5.7 during 24 hr. of aeration.			
							SS	Increased by an average of 76 mg/l from an average initial conc. of 1960 mg/l .			
							BOD	Approximately 26% removal in 24 hr.			
							OU	Almost twice as much O_2 consumed in 24 hr. by the chemcial fed unit as by the control Up to 13% of TOD was exerted in 24 hr.			

* Refer to Reference No. 15 for respirometer data

1	2	3	4	5	6	7	8	9	10	11	12
Urea	OR	SHC NAR	CN CO	21	1200 mg/l		OU	Oxygen consumption of chemical fed units was less than 0.15 the consumption of the control units.	2j 3l 3k 4a 5a 5b 5e 5g 5h 5l 5t	Inhibited oxygen consumption.	52
					720 mg/l		OU	Oxygen consumption was inhibited when pure culture zoogleal sludge was used.			
Urethane	OR	SHC NAR	CO CN	18			OU	Toxicity reflected by complete inhibition of oxygen uptake for up to 144 hr. of oxidation even when additional metabolizable substrate was present.	1b 2j 3l 3q 4d 5e 5h 5t	None of TOD exerted in 144 hr. of oxidation.	44
m-Xylene o-Xylene p-Xylene	OR	HC AR		18	500 mg/l		OU	Chemical was toxic during first 24 hr. of aeration.	1b 2j 3l 4d 5e 5g 5h 5i	Order of increasing toxicity: o-Xylene, m-Xylene, p-Xylene.	45

1	2	3	4	5	6	7	8	9	10	11	12
Zinc (as Zn^{+2} & cyanide complexes)	IN	CA	HM	05	5 mg/l to 10 mg/l		G	Lowest continuous dose that causes an effect.	6a	Cyanide complexes of zinc produced reactions similar to those of the zinc sulfate salts.	46
					160 mg/l			Lowest 4 hr. duration slug dose which would produce a 24 hr. effect on the effluent.			
					10 mg/l	89%	SMC	63% of added metal found in activated sludge and 14% in the raw sludge.			
					56 mg/l		SMC	Zinc in the raw sludge was 35 times > in the sewage.			
Zinc (Zn^{+2})	IN	CA	HM	05	160 mg/l		G	Slug dose over 4 hr. resulted in serious plant upset for 30 hr; normal operation was re-established in 40 hr.	1b,2h 3l,3p 4b,5b 5c,5h 5i,5k	Higher forms of microorganisms were not seriously affected by slug dose of zinc.	12
Zinc (Zn^{+2})	IN	CA	HM	05	1.5 mg/l		SMC	58% of metal immobilized in sludge.	1c 4c	Grand Rapids, Michigan.	58
					0.3 mg/l		SMC	85% of metal immobilized in sludge.		Richmond, Ind.	
Zinc (Zn^{+2}) (contd.)	IN	CA	HM	05	2.2 mg/l	91%			1c,2i 3l,4c 5a,5b 5c,5h 5j,5k	Bryan, Ohio overall removal.	5
					1.5 mg/l	47%				Grand Rapids, Michigan -	

1	2	3	4	5	6	7	8	9	10	11	12
Zinc (contd.)										overall removal.	
					0.3 mg/l	66%				Richmond, Ind. overall removal.	
					1.8 mg/l	89%				Bryan, Ohio-secondary removal.	
					1.0 mg/l	20%				Grand Rapids, Michigan - secondary removal.	
					0.4 mg/l	75%				Richmond, Ind. secondary removal.	
										Influent zinc was found primarily in the insoluble form and was removed more effectively than chromium, copper, or nickel.	
Zinc as Zn^{+2} (contd.)	IN	CA	HM	05	7.5 ppm		SVI	After 30 min. contact, zinc caused 89%, 105%, and 86% decrease in SVI for activated sludge solids conc. of	31 4a 5e 5h 51	Zinc readily adsorbed by activated sludge; as conc. in-	57

1	2	3	4	5	6	7	8	9	10	11	12
Zinc (contd.)								500, 1000, and 2000 ppm, respectively.		creased, zinc removal increased. Fresh solids and ripe solids removed less zinc than did activated sludge. At 7.5 ppm zinc and 1000ppm activated sludge solids total removal achieved after 30 min. contact.	
					15 ppm		SVI	After 30 min. contact, zinc caused a 80%, 92%, and 110% decrease in SVI for activated sludge conc. of 500, 1000, and 2000 ppm, respectively.			
Zinc (Zn^{+2})	IN	CA	HM	05	2.5 mg/l		CR	13% in primary treatment.	1b,2g 3l,3p 4b,5b 5c,5h 5i,5k	Zinc removal in primary treatment was minimal. Zinc removal decreased with increasing zinc conc. Zinc in primary effluent was primarily in insoluble form.	12
					10 mg/l		CR	14% in primary treatment.			

1	2	3	4	5	6	7	8	9	10	11	12
Zinc (as Zn^{+2} and complexed with cyanide)	IN	CA	HM	05	2.5 to 20 mg/1	95% to 74% respectively	CR	Minor removal in primary treatment; microbial floc in secondary treatment adsorbs much zinc.	1d 2g 31 3p 3q 4b 5b 5c 5e 5h 5j	Zinc sulfate and complexed zinc cyanides were studied. Their effects were similar in acclimated systems.	48
							T	$ZnSO_4$ did not affect turbidity after a few hrs. acclimation. Decreasing the cyanide conc. in $Zn(CN)_2$ complex sutdies resulted in improved effluent turbidity.			
							BOD	At Zn conc. of 20 mg/1 BOD removal efficiency was reduced 2%.			
							G	Maximum Zn conc. which does not cause significant effect on treatment efficiency was 2.5 mg/1 to 10 mg/1.			

1	2	3	4	5	6	7	8	9	10	11	12
Zinc (as Zn^{+2}, and complexed with cyanide)	IN	CA	HM	05	2.5 mg/l	95%	BOD	BOD removal efficiency decreased slightly.	1b,2g 31,3p 4b,5b 5c 5h 5i 5j 5k	Zinc as zinc sulphate and zinc cyanide were studied. After acclimation, both forms of Zn produced similar results. The threshold concentrations of Zn that would significantly affect treatment were 2.5 mg/l to 10 mg/l. At up to 10 mg/l of Zn in sewage, the Zn in the final effluent existed primarily in an insoluble form. At 20 mg/l Zn in sewage, the form of Zn in the final effluent	12
					10 mg/l	89-96%					
					20 mg/l	74%	SMC	Activated sludge adsorbed zinc.			
							T	Acclimation of activated sludge to zinc cyanide complex resulted in decreased effluent turbidity. No acclimation was necessary for $ZnSO_4$.			
(contd.)											

1	2	3	4	5	6	7	8	9	10	11	12
Zinc (contd.)										existed primarily in solution.	
Zinc (Zn^{+2})	IN	CA	HM	05	0.005 to 0.5 mg/l		MI	Although no conc. showed stimulation, 0.08 to 0.5 mg/l inhibited growth.	1d 2k 3k 4a 5a	Growth of *Nitrosomonas* studied.	39
Zinc (Zn^{+2})	IN	CA	HM	05	0.91 mg/l		CR	Primary sedimentation reduced Zn conc. by about 40%. Lime was most effective precipitant. Sulfuric acid suppressed sedimentation of Zn. Activated sludge removed about 60% of the Zn.	1b 2g 3l 4c		61
Zinc (Zn^{+2})	IN	CA	HM	05	1 to 10,000 ppm		OU	1 ppm significantly inhibits O_2 uptake.	2h 3l 4d 5e 5g 5h	Most toxic cation out of the 12 cations studied.	15

1	2	3	4	5	6	7	8	9	10	11	12
Zinc and Cadmium Mixture	IN IN	CA CA	HM HM	05 05	10 ppm zinc, 10 ppm cadmium		OU	The Zn-Cd mixture was more toxic or inhibitory than was either element individually.	2h,31 4d,5e 5g,5h		15
Zinc and Manganese Mixture	IN IN	CA EL SA	HM HM	05 05	10 ppm zinc, 100 ppm manganese		OU	The Zn-Mn mixture was more toxic or inhibitory than was either element individually.	2h,31 4d,5e 5g,5h		15
Zinc (element and compounds)	IN	EL SA	HM	01 02 05	10,000 mg/l		OU	O_2 consumption of Zn dust fed unit was 34% of that of the control unit.	2h,31 4d,5e 5g,5h	Zinc compounds in order of decreasing toxicity were: zinc dust, zinc granulated, zinc oxide.	15
					10 mg/l zinc		OU	Conc. was slightly inhibitory or toxic.	2h,31 4d,5e 5g,5h	Zinc compounds in order of decreasing toxicity were: zinc sulfate, zinc acetate.	

1	2	3	4	5	6	7	8	9	10	11	12
Zineb ®	OR ST	SHC NAR	CN CS	11			OU	Slowly oxidized with 5 to 20% of COD exerted.	4d 5c 5g	Insecticide.	53
							CR	Chemical was slightly degraded.			
Ziram ®	OR ST	SHC NAR	CS CN	11			OU	Chemical was slowly oxidized with 5 to 20% of COD exerted.	4d 5c 5g	Insecticide.	53
							CR	Chemical was slightly degraded.			

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